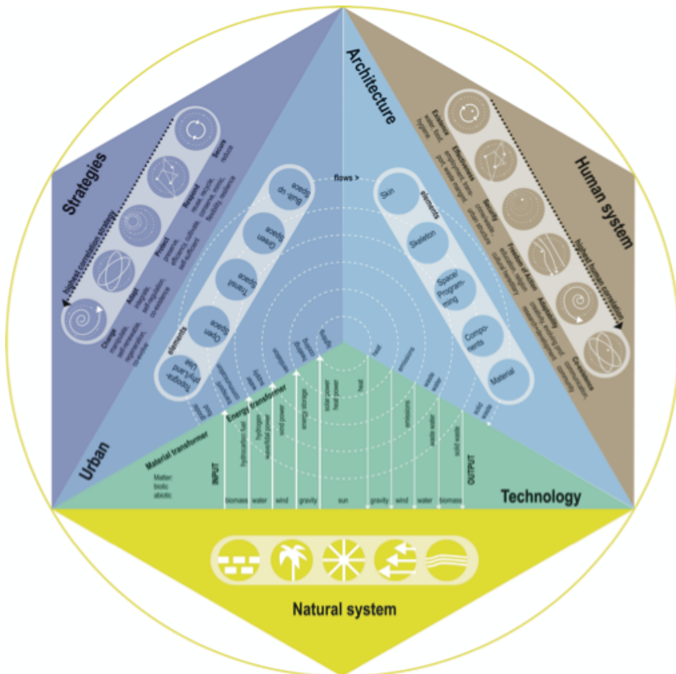
CORRELATOR

CORRELATOR FOR STRATEGIES FOR AN ECOLOGICALLY ADAPTABLE URBAN AND ARCHITECTURAL DEVELOPMENT

A SYSTEM CORRELATION OF THE NATURAL, HUMAN AND BUILT ENVIRONMENT EXEMPLIFIED ON THE DESERT URBANISATION IN OMAN

DANIELA A. OTTMANN



CORRELATOR FOR STRATEGIES FOR AN ECOLOGICALLY ADAPTABLE URBAN AND ARCHITECTURAL DEVELOPMENT.

A SYSTEM CORRELATION OF THE NATURAL, HUMAN AND BUILT ENVIRONMENT EXEMPLIFIED ON THE DESERT URBANISATION IN OMAN.

Von der Fakultät für Ingenieurwissenschaften der Universität Duisburg-Essen zur Erlangung des akademischen Grades eines Doktor Ingenieur (Dr.-Ing.) genehmigte Dissertation

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Abstract

40 years after "The limits to growth" the post oil boom economy affects countries in resource scarce environments like the Arabian Peninsula in the Middle East with expanding urbanization. Those cities and architectures are based on fossil fuel driven technologies to control the surrounding arid hot climate for the benefits of human comfort. As a result skyscrapers are flourishing out of desert sands. Their ecological footprint in terms of resource consumption and the resulting emissions is nearly six planet earths, but celebrated by imported quantitative evaluation methods from North America or Europe with platinum medals for sustainable building practices. This dichotomy displays the global quest for 'sustainable' development on the one hand side and the lack of integrating the inherent bio-climatic, socio-cultural and political-economical prerequisites of those newly developing countries on the other. Whereas traditional desert oases settlements have been as self-sufficient and self-organising systems perfectly interconnected with all prevalent natural resources and cultural conditions inherent to the region. Such integral understanding draws on the logic of the immanent relations of the natural, human and built environment or in other words on ecology.

An ecological understanding is used in this work to determine the qualitative relationships of urban and architectural (built) environments in conjunction to prevalent natural (ecosphere) and human (anthroposhere) conditions. On the assumption that the built environment acts as levelling layer between the human and the natural environment in order to compensate bio-climate conditions for the comfort of social-cultural context desires, the main research question raises as such: How can cities and architectures become support systems (rather than energy and resource consumers) that have the properties to co-evolve as cooperative sub-systems with the surrounding natural and human preconditions under the rules of ecology in general? And in particular: How can the concept of a traditional self-sustaining desert oasis provide future strategies for sustainable development of cities and architecture?

Rules of ecological systems are understood here as instruments to an appropriate urban planning that follows the principles of higher adaptability and self-organization patterns to generate conditions. System theories are consulted to determine principles and strategies of complex viable systems of nature. These then form the matrix for analysis of case studies on urbanization patterns of pre-and post-oil era in the Sultanate of Oman on the Arabian Peninsula and are used to extrapolate potentials and missing links within urban systems through support strategies. Those results are further transferred into a general model of interconnections (Correlator) of components of urbanism, architecture and technologies in conjunction to the natural and human environment.

The resulting model provides a correlation matrix that orders elements and flows from the natural to the built environment via considering principles of human systems and strategies of ecological systems. It proposes a template of possible elements and strategies for interconnection, which determine the quality of adaptable, viable and thus 'sustainable' urban environments. The Correlator shows possibilities and fields of action for the holistic thinking of architecture and urbanism as support system and thus for the decision-making processes in planning, policy, and the design of the built environment.

Finally this work demonstrates strategies for 'sustainable development' where the correlation matrix and the knowledge of the quality of ecological network connections proposes an aide-memoir to de-specify the tunnel-visioned expertise of past innovations and prioritizes 'Vernetztes Denken' for newly meaningful concepts for a new planning culture that enable viable urban and architectural development, not only within desert regions.

Daniela A Ottmann (February, 2015)

Zusammenfassung

40 Jahre nach "Die Grenzen des Wachstums" ermöglicht die Post Ölboom Wirtschaft Ländern in Ressourcen knappen Umgebungen wie der arabischen Halbinsel im Nahen Osten eine steigende Urbanisierung. Städte und Architekturen werden von fossilen Technologien gesteuert, um das aride heiße Klima für den menschlichen Komfort anzupassen. Als Ergebnis sprießen Wolkenkratzer aus dem Wüstensand. Deren ökologischer Fußabdruck in Bezug auf Ressourcenverbrauch und die daraus resultierenden Emissionen von fast sechs Planeten Erde floriert, werden aber von importierten quantitative Bewertungsmethoden aus Nord Amerika oder Europa mit Platin-Medaillen für nachhaltiges Bauen Praxis gefeiert. Es wird deutlich, dass die globale Suche nach "nachhaltiger" Entwicklung im Konflikt zu einer Integration von inhärenten bio-klimatischen und soziokulturelle Voraussetzungen dieser Entwicklungsländern steht. Städte materialisieren sich mittlerweile durch quantitative neo-liberale Wirtschaftsmotive, während traditionelle Wüstenoasen Siedlungen als autark und selbstorganisierende Systeme perfekt mit allen gängigen natürlichen Ressourcen und kulturellen Bedingungen der Region verbunden waren. Ein solches ganzheitliches Verständnis stützt sich auf die Logik von immanenten Wechselbeziehungen natürlicher, menschlicher und gebauter Umwelt oder mit anderen Worten auf Regeln der Ökologie.
Ein ökologisches Verständnis wird in dieser Arbeit verwendet, um qualitative Zusammenhänge städtebaulicher und architektonischer Umgebungen in Verbindung zu natürlich (Ökosphäre) und menschlich (Anthroposphaere) herrschenden Bedingungen zu bringen. In der Annahme, dass die gebaute Umwelt als Ausgleichsschicht zwischen der menschlichen und der natürlichen Umwelt wirkt, um bio-klimatische Bedingungen dem Komfort im sozial-kulturellen Kontext zu kompensieren, ergibt sich die zentrale Forschungsfrage: Wie können Städte und Architekturen unterstützende Systeme (eher als Energie und Ressourcen Verbraucher) werden, die als kooperative Teilsysteme mit den umgebenden natürlichen und menschlichen Voraussetzungen nach den Regeln des Ökologie funktionieren? Und im speziellen: Wie kann das Konzept einer traditionellen selbsterhaltende Wüstenoase Zukunftsstrategien für eine nachhaltige Entwicklung der Städte und der Architektur liefern?
Regeln ökologischer Systeme werden hier als Instrumente verstanden, um eine angemessene Stadtplanung, die den Prinzipien der höheren Anpassungsfähigkeit und Selbstorganisation Muster folgt, zu erzeugen. Systemtheorien werden konsultiert, um Prinzipien und Strategien von komplexen lebensfähigen Systemen zu ermitteln. Diese bilden dann die Analysematrix für Fallstudien an Urbanisierungsmustern aus Pre- und Post Öl-Aera im Sultanat Oman auf der arabischen Halbinsel und dienen dazu etwaige Potenziale und fehlende Verbindungen innerhalb urbaner Systeme und

Support-Strategien zu extrapolieren. Diese Ergebnisse werden weiter transferiert in ein generelles Modell von Verbindungen (Correlator) der Komponenten von Stadt, Architektur und Technologien im Bezug auf ihre natürliche und menschliche Umwelt.

Das resultierende Korrelationsmodell bietet eine Matrix, die Elemente und Flüsse von der natürlichen zur gebauten Umwelt in Einklang mit Prinzipien menschlicher Systeme und Strategien ökologischer Systeme stellt. Als Schablone möglicher Stadt- und Architekturkomponenten und Verbindungsstrategien, kann somit die Qualität hinlänglich ihrer Anpassungsfähigkeit, Lebensfähigkeit und somit "Nachhaltigkeit" eingestellt werden. Das Ergebnis zeigt Möglichkeiten und Handlungsfelder für ein ganzheitliches Denken auf, Architektur und Städtebau als Support-System zu sehen, um Entscheidungsfindungsprozesse in Planung, Politik und der Gestaltung gebauter Umwelt zu unterstützen.

Der Correlator und das Wissen um die Qualität ökologischer Netzwerkverbindungen ergibt somit eine Gedankenstütze für den Ansatz, Stadt, Mensch und Natur vernetzt zu denken, um sinnvolle Konzepte für lebensfähige Städte und Architekturen in spezifischen bio-klimatischen und soziokulturellen Gegebenheiten über Wüstenregionen hinaus zu ermöglichen.

Daniela A Ottmann (Februar, 2015)

Deutscher Titel:

Korrelator für Strategien für eine ökologisch anpassungsfähige städtebauliche und architektonische Entwicklung.

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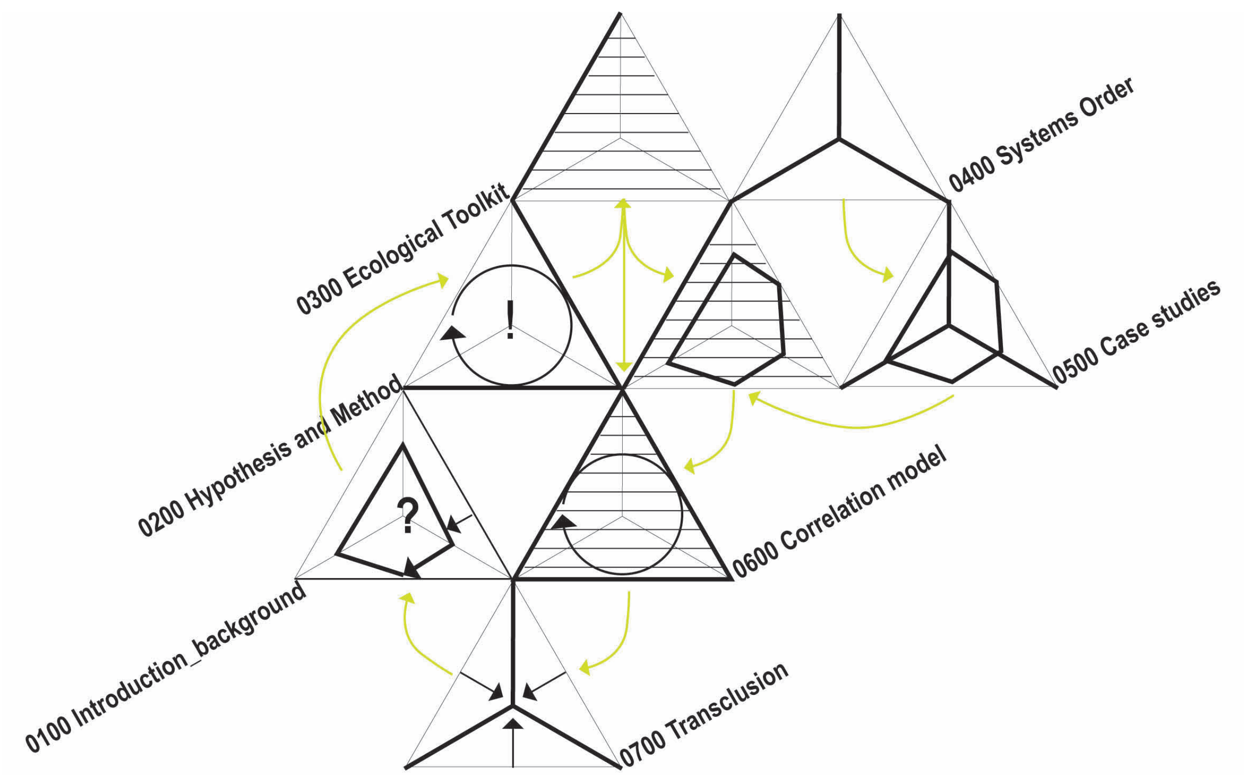
0400 Systems Order
0300 Ecological Toolkit
0500 Case studies
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Abbreviations

AC	Air conditioning
BCE	Before the Common Era
BREEAM	Building Research Establishment (BRE) Environmental Assessment Method
DGNB	Deutsche Gesellschaft fuer Nachhaltiges Bauen
EU	European Union
GCC	Gulf Cooperation Council
GHG	Greenhouse Gas Emissions
ha	Hectare
HVAC	Heating, ventilating and air conditioning
IAE	International Energy Agency IEA
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
IUCN	International Union for Conservation of Nature
kWh	Kilowatt-hour(s)
LCA	Life cycle analysis/Life cycle assessment
LEED	Leadership in Energy and Environmental Design
MCA	Muscat Captial Area
MFA	Al Mansafah in Ibra Governorate
OECD	Organisation for Economic Co-operation and Development
PV	Photovoltaic
SBCI	Sustainable Buildings and Climate Initiative
SCP	UN-Habitat’s Urban Environment Section, the Sustainable Cities Program
UAE	United Arab Emirates
UK	United Kingdom
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
US	United States of America
WCED	World Commission on Environment and Development
WWF	World Wildlife Fund

Glossary

Abiotic Abiotic materials are all materials taken directly and unprocessed from nature and are not renewable in hundreds of years, e.g. ores in a mine, “unused extraction of raw materials”, excavation of earth and sediment etc.

Anthroposphere Human environment: from Greek *anthrōpos* ‘human being.’ from Greek *sphaira* ‘ball.

Biome A large naturally occurring community of flora and fauna occupying a major habitat (Oxford dictionaries, 2013)

Biosphere The regions of the surface, atmosphere, and hydrosphere of the earth (or analogous parts of other planets) occupied by living organisms. (Oxford dictionaries, 2013)

Biotic Biotic materials are all organic materials taken directly from nature, before processing, (e.g. trees, fish, fruits, cotton).

Built environment human induced and produced environment. a permanent part of a structure, system, or situation; specifically architecture and urban structures.

Correlator A reference matrix of system strategies to link human, natural and built environment under the rules of ecology. As *Bezugssystem* of components of urbanism, architecture and technologies in conjunction to the natural and human environment it can be used through strategies of system science to achieve adaptable, viable and thus ‘sustainable’ interrelations between anthroposphere, ecosphere and built environment. (Regionally applied to hot arid desert biomes.)

Cycles Cycles: A series of natural, but also technical substance flows can occur in cycles. A typical example is the natural water cycle. Dematerialization is the radical reduction of natural material resources for satisfying human needs by technical means. Neither environmental nor economic sustainability can be attained without dematerialization.

Ecological footprint The impact of a person or community on the environment, expressed as the amount of land required to sustain their use of natural resources. (Oxford Dictionaries, 2013)

Ecology Science that deals with the relations of organisms to one another and to their physical surroundings (Oxford dictionaries, 2013)

Ecosphere Natural environment = biosphere, lithosphere, hydrosphere, atmosphere, pedosphere: interaction between the living and nonliving components is emphasized.

Ecosystem A biological community of interacting organisms and their physical environment. (Oxford dictionaries, 2013)

Efficiency The effectiveness, with which means are introduced into an existing process in order to attain a defined output (see, in contrast: productivity).

Emission Emissions are material contaminations of the air, noises, vibrations, light, heat, radiation, and similar energetic or material phenomena, which come from a facility, a vehicle or piece of equipment.

Entropy A thermodynamic quantity representing the unavailability of a system's thermal energy for conversion into mechanical work, often interpreted as the degree of disorder or randomness in the system. (Oxford dictionaries, 2013)

Estidama Estidama is a sustainable urban planning initiative developed by the Abu Dhabi Urban Planning Council and is based on the four pillars of sustainability: environmental, economic, cultural and social. The initiative includes the Peal building rating system as part of the Estidama integrated design initiative.

Goods All food, products and processed materials infiltrated into the urban network.

Hydro-carbons A compound of hydrogen and carbon, such as any of those that are the chief components of petroleum and natural gas (Oxford dictionaries, 2013), based on fossil and hence non-renewable (at least for the predicted life time of the homo sapiens sapiens) energy sources.

Input Input includes everything that is employed in a process. For the urban metabolism biotic, abiotic, water, air and sun are considered as input factors in this study.

Output Output encompasses everything that results from a process, a procedure or a behavior. According to input factors again wastes of biotic, abiotc, water, gaseous emissions or heat is considered.

Process Process is the procedure (machine, method, use), during which the inputs are convert- ed into outputs, by means of an action. By which, at least one intended output is produced, (e.g. effectiveness of a city through employment opportunities).

Sustainability The ability to sustain is a mere concept. In specific it has to be asked what should be sustained, under which conditions or even what condition and what time frame is used to indicated something to endure.

Glossary of Arabic terms:

aflaj	(sing. falaj) intricate networks of irrigation systems; over- and underground
hara	(pl. harat) the central quarter
hurmah	pre-Islamic notion of the sacred and protected time
juss	fine lime cement mortar
majlis	(pl. majalis) male meeting halls
majlis al-shura	lower chamber of the legislative branch of the government
masjid	district mosque
masjid al juma	Friday mosque
mintaqah	region
muhafazah	governorate
sabla	meeting space for men, male meeting halls
sarouj	artificial hydraulic pozzolan lime cement mortar
shura	
souq	open-air market, often partly covered
sur	surrounding wall
wadi	valleys or riverbeds that are dry except in the rainy season
wali	governor
wilayat	governmental districts

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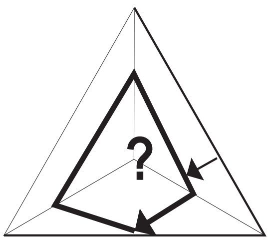
0000 Introduction

> *We travel together, passengers on a little spaceship, dependent on its vulnerable reserves of air and soil; all committed, for our safety, to its security and peace; preserved from annihilation only by the care, the work and the love we give our fragile craft. We cannot maintain it half fortunate, half miserable, half confident, half despairing, half slave — to the ancient enemies of man — half free in a liberation of resources undreamed of until this day. No craft, no crew can travel safely with such vast contradictions. On their resolution depends the survival of us all.*
> *(Adlai Ewing Stevenson II, Speech to the UN Economic and Social Council, Geneva, Switzerland (9 July 1965) in Stevenson, 1965, p. 224)*

Almost 50 years after the warnings by Adlai Stevenson we are watching cities and skyscrapers flourishing out of desert sands, which are celebrated with platinum medals for sustainable building practice.
The post oil boom economy affects the countries in the Middle East with rising population figures that demand development of cities based on fossil fuel driven technologies to control the surrounding arid hot climate of the desert for the benefits of human comfort.
An increasing scarcity of resources in those hot arid climate zones impedes the supply for the rising demand especially for the energy consumer and pollutant producer giant: built environment.
To comply with the global goal to accept environmental challenges of climate change through concepts of sustainable development, the dichotomy of resource meagre desert and expanding cities, lead to current phenomena of “green” cities within a desert from scratch like Masdar City in the UAE. Cities on the Arabian Peninsula of the Middle East are desperately trying to find ways to integrate environmental, socio-cultural requirements beyond the purely economically driven aspects of city making as property and real estate.
The current situation is outlined with a rising demand of built environment on the one hand and on the other hand the scarcity of research to approach a sustainable development of architecture and urbanism that is linked to the existing fabric of biosphere and anthroposphere of emerging regions. Recent established industries, education and research facilities draw mainly on imported knowledge and technologies from elsewhere in the world in order to meet the needs of oil-revenue triggered construction boom, which contradicts all discussions on energy, and resource efficient management strategies as currently discussed in most part of the world. In order to solve the overconsumption of energy and resources, assessment systems from North America or Europe have been introduced the construction industry and government levels, without determining the inherent

socio-cultural, political-economical and ecological prerequisites of those newly developing countries.
A paradigm shift to those quantitative evaluation formulas is needed to adjust the built environment to the local situation of local resources in natural and human systems.
Just like desert oases in the past have been as a system perfectly interconnected with all prevalent resources, energy and information inherent to the region. The analysis of oases systems as ecologically adapted urban systems within hot arid desert climate zones on the Arabian Peninsula can lead to a strategic understanding to correlate elements of human systems, natural environment and the compensation layers of urbanism, architecture and technology.

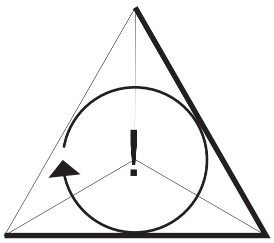


The intended research aim

The intent of this work is to establish a reference system that can be used to determine the comprehensiveness of existing systems of the built environment and of planned environments. This model of interconnections can work as a tool to discover potentials and missing links within the reference system that supports strategies and decision-making processes in planning, policy, and design of the built environment in different levels urban and architectural environments.
In order to shift the current practice of quantitative evaluation of sustainability into a qualitative integrative approach to connect all elements of urbanism and architecture to prevalent natural resources under the circumstances of human conditioning, a model of correlation of concurrent elements and flows necessary to interlink in the most effective way through strategies deriving from natural systems need to be established. Thereby a ratification of quantities or any approach of rating the inter-connections between the different elements in order to assess “qualities’ will be referred to in future research which could establish mapping tools for qualitative (urban/architectural) system analysis and design. This work aims first of all to establish the blank ‘code’ of how the different elements in architecture and urbanism of the built environment are connected to the natural resources and flows and the complexity levels of the human system.
A new mode of understanding theories and practices of architecture, urban design and planning is envisioned to read, understand and adapt complex urban systems to the environmental factors of specific regions like hot arid desert ecozones, with the overall aim to achieve liveable, viable and adaptable living environments.

Core thesis

Reading oasis settlements as examples of thousands of years old self-sufficient and self-organising systems, provides new insights for built environments adapting to natural and anthropogenic environments. Those insights can be transferred and adapted to present day purposes of architectures and cities. A synergetic approach is envisioned where contemporary complex systems of cities are interconnected with given environmental conditions. In a thinking model of strategic system links an application is thinkable for the regional environment of arid hot deserts within the prevalent socio-cultural dimensions of the Middle East, but also globally.



Hypothesis

A reference system (Bezugssystem) of components of urbanism, architecture and technologies in conjunction to the natural and human environment can be used through strategies of system science to achieve adaptable, viable and thus ‘sustainable’ interrelations between anthroposphere, ecosphere and built environment applied to hot arid desert biomes. (Context: Arid hot desert | Arabian Peninsula | Oman)

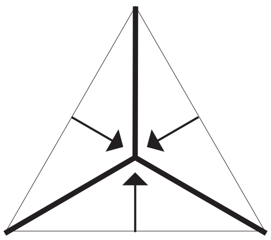
Research questions

The built environment exists of various scales of physical materialization of inputs of flows and resources linking to the natural surrounding as source on the one hand side. Beyond this context the human environment has equally social and cultural context. Those dynamics have previously determined the shape and form of the built environment of desert oasis settlements with a huge emphasis on dependencies on climate, resource and geological/geographical context The interaction of those determinants have shaped the physical surrounding without those of active technology Within the assumption that the built environment acts as a layer/membrane/skin between the human and the natural environment in order to compensate bio-climate conditions to the comfort, a social-cultural context desires, the research questions to be asked are:

First_ How is the built environment connected to complexities, hierarchies and orders of ecological and social systems?

Second_ How can traditional self-sustaining desert oasis settlement systems be transferred to future strategies of sustainable development for cities and architecture?

Third_ Which strategies can lead to a high level of adaptability and viability of the built environment in general?

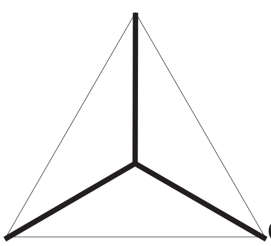


Scientific relevance

Different to quantitative measuring tools (and their limitations within an ecological understanding see →0100), the correlating matrix in 'Learning from Desert Oasis Systems' identifies interdependent areas in order to establish and achieve a higher connectivity amongst them. It combines ecological principles with concepts or strategies for making urban and architectural built environments. Going beyond the current strategies of minimizing the impact on natural resources (like reduce, reuse and recycle), it is possible for new research and development fields to be diagnosed, where current active and passive technology levels are not enough to achieve higher adaptabilities. Those strategies enable concepts to shape the built environment according to the prevalent conditions of the biosphere (natural environment) and anthroposphere (human environment).

Through considering the overall ecosphere and human environment, it expands on a holistic view of the urban system. The thinking matrix can be used in the different stages of design, construction, operation, evaluation, planning and finance from different stakeholders.

Understanding the elements and flows as components of a global matrix of determinants onto the built environment can support designer, planner and decision makers in their connection to prevalent patterns of context and hence contributes to the quest for viable living environments beyond the specialist output of technologies or shapes.

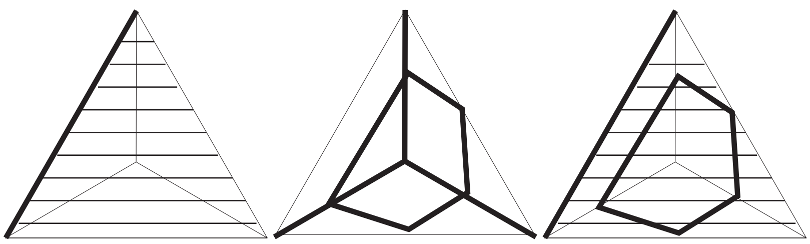


Organisation of the research

The proposed organisation of the thesis follows an argumentative logic built up in six parts. Firstly the Discussion and Statement of the Problem will give an overview of the outlines of the thesis topics. Thus leading into to the hypothesis.

In order to prove the hypothesis background theory and methods are being introduced as ecological toolkit. In this part of the work the perspective of system theories are being studied in order to apply those to an underlying structure of a reference system as stated in the hypothesis. Furthermore possible strategies of existing self-organizing systems give a first dimension to relate the following: human environment, natural environment and built environment. Those are subject to fur-

ther analysis regarding elements that can be related to each of the system axes in the following third part.
There the first findings on correlated components within the human, natural and built environment are described.
The fourth part will assign theoretical systems elements and orders to case studies of regional settlements, architectures and technologies. Followed by the analysis of traditional oasis settlement systems by evaluating underlying fieldwork studies of Oasis settlements in Oman. Those results are then compared to current practice and future proposals of built environment in the region (Muscat Capital Area).
The composition of the third (System theories and strategies), fourth (system orders) and fifth part (systems elements of architecture, urbanism and technologies) leads into a model of correlations of the above applying the relations between natural, human and built environment through strategies of ecological system theories.
This correlation model is now discussed on the case studies of the fifth part and comes up with recommendations of potentials of higher interconnectedness of the model axes comprising natural, human, built (urbanism, architecture, technologies) environment and strategies.
The last chapter will conclude in an outlook and discussion of the possibilities for further research and application of the thinking model as developed in this thesis.



Methodological structure of the thesis
The study is structured into theory, analysis and concept excluding the introduction and the conclusion.
The structure of the proposed dissertation can be divided into the main body of research and literature review. Through the empirical research of theories, the discussion leading into the statement of the problem can be proven. After formulating the hypothesis again literature review is being used to compile the necessary background and theories in order to establish a method of further analysis and assessment of findings and possible solutions as the main part of the research. Equipped with those tools case studies of urban settlements of the past, the present and proposals for future developments in the Middle East are being evaluated through the introduced correlation model compiled of findings in the literature review.

The research and analysis of ecological system principles in general in combination with the specific case studies lead finally into a concept of correlating layers of the built environment with the ones of the natural and human environment into a matrix of higher interconnectivity. Here the initial research questions should be integrated and answered through:

• Ecological understanding of urban and architectural environment so as to answer the question of 'sustainably' integrated cities and architecture.

• Environmental conditions impact on a morphological intelligence that impact on a new formal/spatial paradigm for architectural and urban design.

• Ecological strategies in urbanism and architecture link the performance capacity of material/natural and human systems with environmental conditions to a dynamic balance.

The main steps of this study's methodology are as follows:

1. Review of system inherent principles and strategies. →0300
2. Identification of elements inherent in urban architecture as a built environment in relation to the natural and human environment →0400 based on a systems perspective as discovered in →0300.
3. Analysis of elements and flows in arid desert urbanism and architecture among cases studies in Oman in pre- and post-hydrocarbon-revenue periods. →0500
4. Comparison of case studies and identification of connection patterns and inherent strategies. →0530
5. Conceptualization of connection patterns - finding theoretical relationships among identified components and strategies as of 0300+0400+0500 in a correlation matrix (Bezugssytem).→0600
6. Discussion of the concept →0620 and recommendation of interconnectivity strategies between the natural, built and human environment. →0630
7. Learning from the developed results, implication possibilities and future research areas. →0700

Further the argumentative logic behind this dissertation ' Learning from Desert Oasis Systems' is outlined through the mapping of input and output to each chapter below:

Mapping of Argumentation Logic per Chapter

Chapter	IN>put	OUT>put
0110	Desert Region of the Middle East and its development	Problems in massive resource consumption. Built environment not contra-productive
0120	'Sustainable development' movement	Rating systems for built environment not designed for Middle East
0130	Quantities of evaluation and qualities of systems	Quantitative approach does not meet the system inherent qualities
0140	Traditional Oasis as ecological system in the desert	Hydrocarbon compromised present development Middle East
0200	Inter connectivity of built, human and natural environment (=ecological system) leads to viable and adaptable development of desert regions	

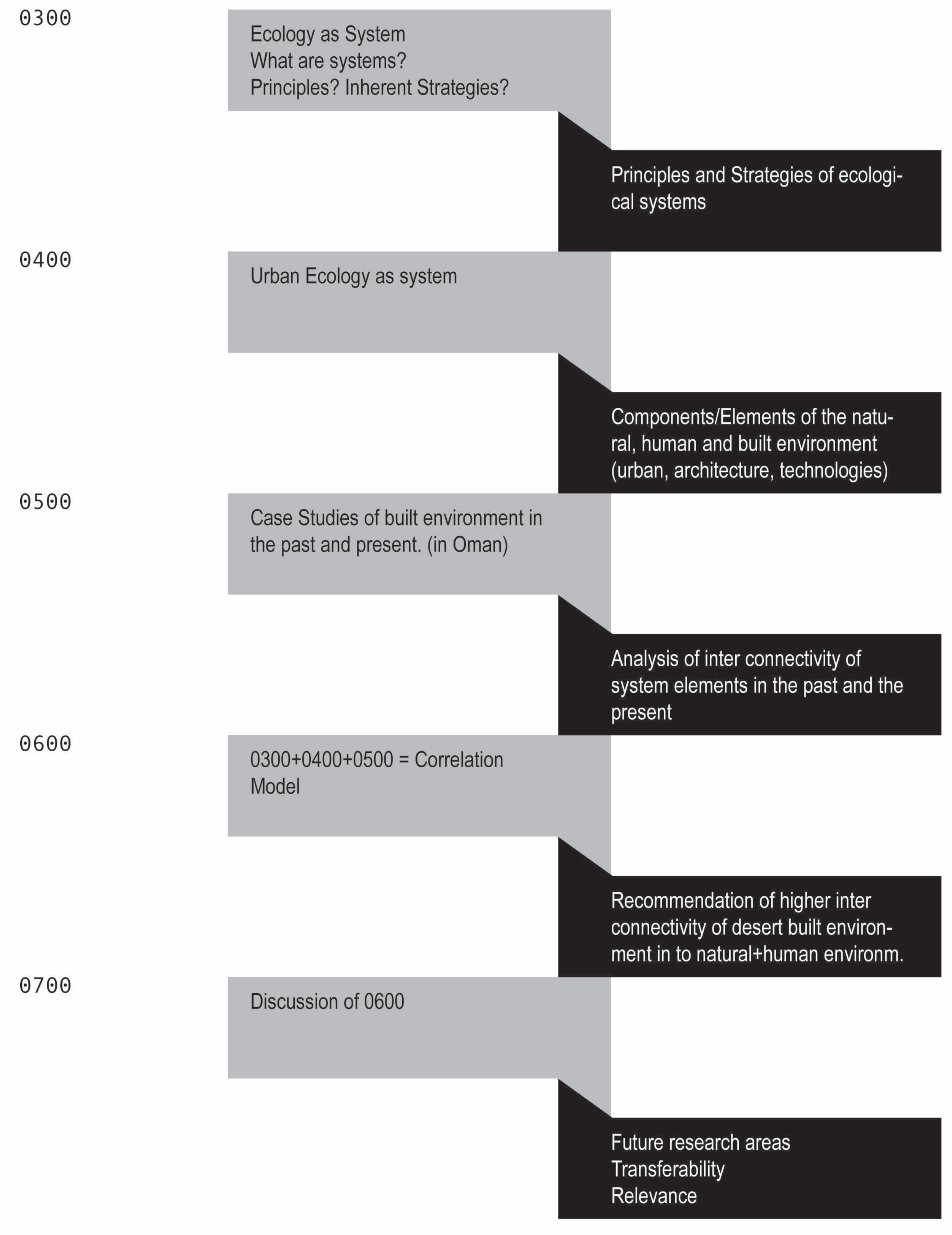
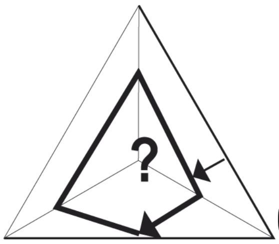


Figure 1 Argumentation logic per chapter



0100 Theory and Context

Synopsis 0100

The introduction to theory and context focuses on two levels: regionally, on conditions of the Arabian Peninsula as an example of resource-scarce[1] environments, and globally, on the discussion concerning 'sustainable development' and its consequences for the built environment.
In →0110 'Conditioning the Desert' the ecology of the region, socio-economic development GCC and challenges of future development (population growth, energy consumption, emissions, water management, resource management) are laid out.
This is followed by an international approach to 'The quest for sustainability' in →0120, where the emergence of "sustainable development", UNEP, Brundtland Report, Agenda 21 and regional adaptation trends are reviewed.
The current technological method of compensating natural and human climates in the built environment of urban (infra-) structures and architecture (fixed factors: human comfort, energy efficiency, thermal climate design, specialization of expert fields) and the rise of 'green building' rating systems are analysed in →0130 'Quantifying Qualities'.
Derived from the regional model of traditional oasis settlements, a global transfer of as integrative approaches (like in the desert oasis system) versus specialisation is questioned in →0140 'The oasis as system'. The two perspectives of specific desert and transferred general understanding of urban systems lead to the postulating of a hypothesis in Chapter 0200.

A rising population with rising habits of comfort drives massive processes of urbanisation, and thereby a rising demand of natural resources will inevitably play the key role in the environmental future of our planet.
This work concentrates on the extreme environmental context of the resources-scarce hot and arid biomes as example of the most extreme conditioning difference between human comfort and natural environment.

[1] hence a global state of the example for future challenges: desertification, lack of potable water, global warming, hot arid environmental challenges, lack of biotic resources.

Global economy streams, based on exports of hydrocarbons in the region of the Arabian Peninsula, have enabled to control the scarce desert environment through introducing comfort-conditioning technologies. Thus the technologies embedded through urbanism and architecture act as mediators between the human being and the surrounding natural environment. Before looking deeper into the context of the development of desert urbanism and architecture on the Arabian Peninsula of the Middle East, several notions on contextual points of view of this work need to be defined.

The Built Environment comprising the physically human built environments like architectural and urban infrastructures via inherent technologies, are examined in this thesis as support structures, conditioning or compensating layers between human systems in order to achieve a certain comfort within the natural system of our planet. Those interdependencies of nature and the human environment via the built environment is the basis of observations elaborating on the quest for 'sustainable development' within the given subject of the Arabian Desert urbanism and architecture, in order to find strategies to achieve viability and adaptability of infrastructural systems within the given bio-climatic and human-social environment. In anticipation of the built environment, the abstract construct of the anthroposphere, in relation to the ecosphere in this work, shall be exemplified first.

The evolution of urbanized civilisation, as a result of the influence of human activity on the natural environment, has separated the human environment from the natural environment. The development has imposed the anthropogenic conditioning layers of agriculture, infrastructure (built environment, architecture, urbanism, technologies), economics, politics, and culture.

Several descriptions for the quest for sustainable development of the relationship between humans and the natural environment can be found in what the UNEP describes as a combination of equal players of economy, ecology, and sociology. Here the author argues with the equal player rights, since all human action in terms of technologies, consumption patterns, and thus also the built environment, depend foremost on the ecological system that is embedded herein.

The artist, designer, architect and theoretician Frederick John Kiesler places human, technology and nature in a triangle which overlaps on the 'man and heredity' as a connecting area between those instances in an article about 'Correalism and Biotechnique' (Kiesler, 1939). In order to explain Correalism as the study of relationships between man and his natural and technological environments he states:

> *This exchange of inter-acting forces I call COREALITY, and the science of its relationships, CORREALISM. The term 'correalism' expresses the dynamics of continual interaction between man and his natural and technological environments.*

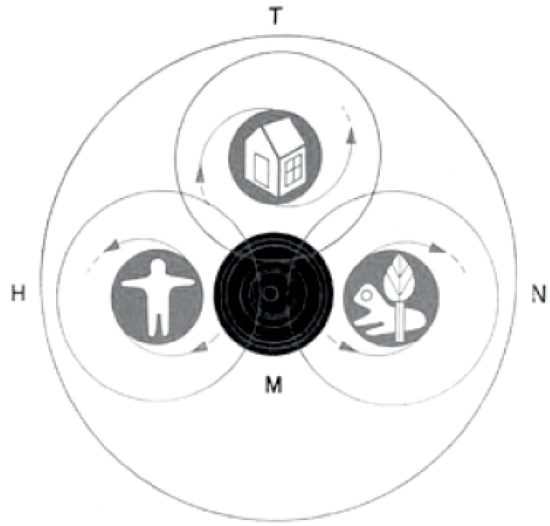


Figure 2→ Man=Heredity + Environment[2] (Kiesler, 1939)

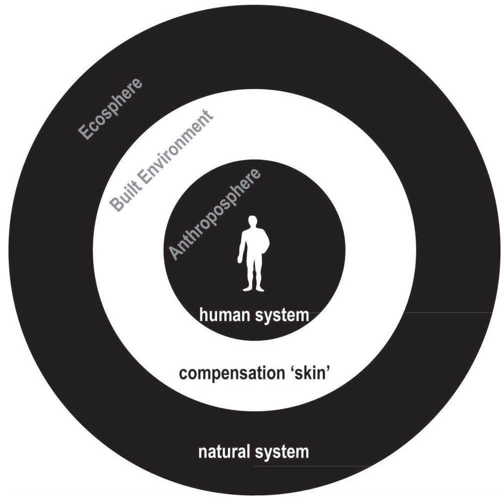


Figure 3→ Built environment as compensation 'skin'

In his theory he sees 'tools, and architecture, created to mediate between man and the natural environment, and they thus form a second imposed 'technological environment'' (Staedman,1979, p.157). On the basis of Kiesler's appeal to investigate new science that serves a 'need-morphology of its[3] growth', the author's investigative perspective takes over the principle of mediation technologies and tools, in specifically the built environment. Nevertheless the human system is seen here as a nested system within the natural environment, which differs from the model described by Kiesler (see Figure 2). The anthroposphere or human system is considered as a sub-system of the natural system and mediated by technological advances of a compensating 'skin' according to human's purpose as shown in Figure 3 above: 'Built environment as compensation 'skin'.'
This work tries not to establish hierarchies within a triangle of pre-postulated, strategic agents of the concept of 'sustainability' (more in →0120) trying to combine society, economics, and ecology, but as a mere understanding of the interconnections between the natural and human environment though the built environment of urbanism, architecture, and inherent technologies as compensation or conditioning strategies for human/social systems.

[2] This diagram expresses the continual interaction of both the total environment on man and the continual interaction of its constituent parts on one another."

[3] Development of technologies or tools to act as mediators between natural and human environments

0110 Conditioning the Desert

"Water, water, water....There is no shortage of water in the desert but exactly the right amount , a perfect ratio of water to rock, water to sand, insuring that wide free open, generous spacing among plants and animals, homes and towns and cities, which makes the arid West so different from any other part of the nation. There is no lack of water here unless you try to establish a city where no city should be." (Abbey,1990).

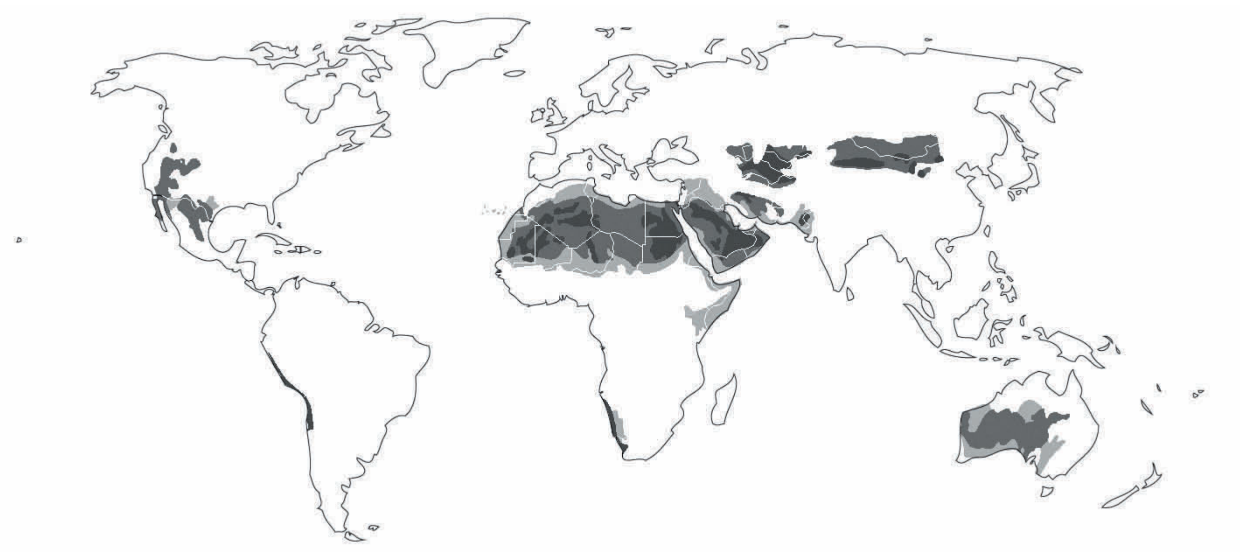


Figure 4→ Arid Desert (dark grey), Xeric Scrublands (medium grey) and Semiarid Desert (light grey)

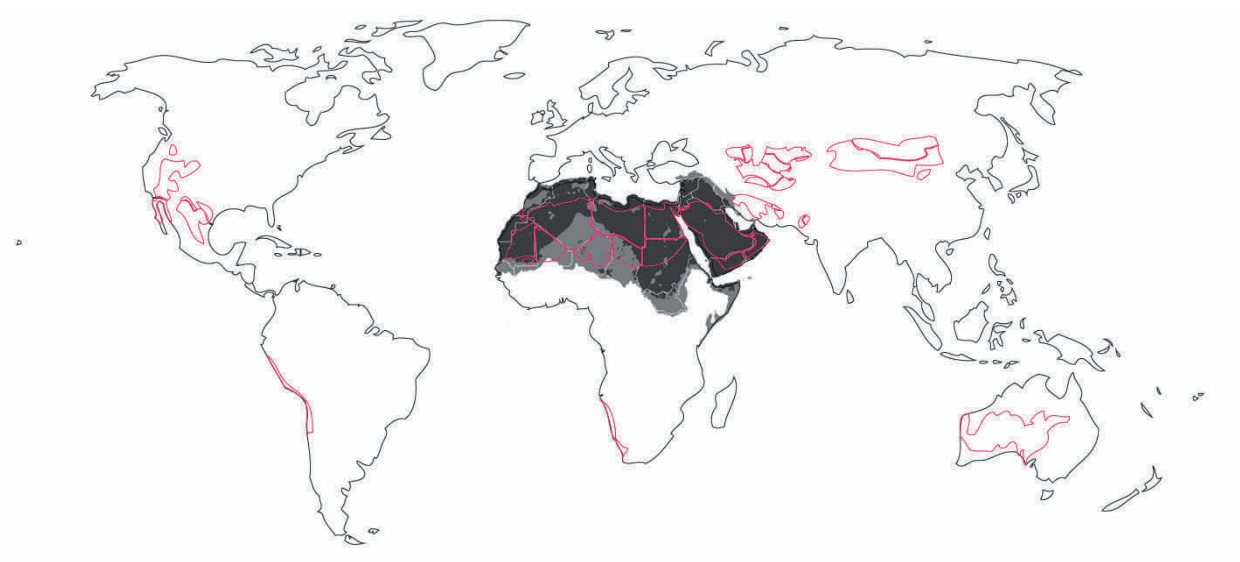


Figure 5→ Map of Arabic speaking regions (dark grey: Arabic as major language, light grey: Arabic as minor language, pink: arid and semiarid desert regions)

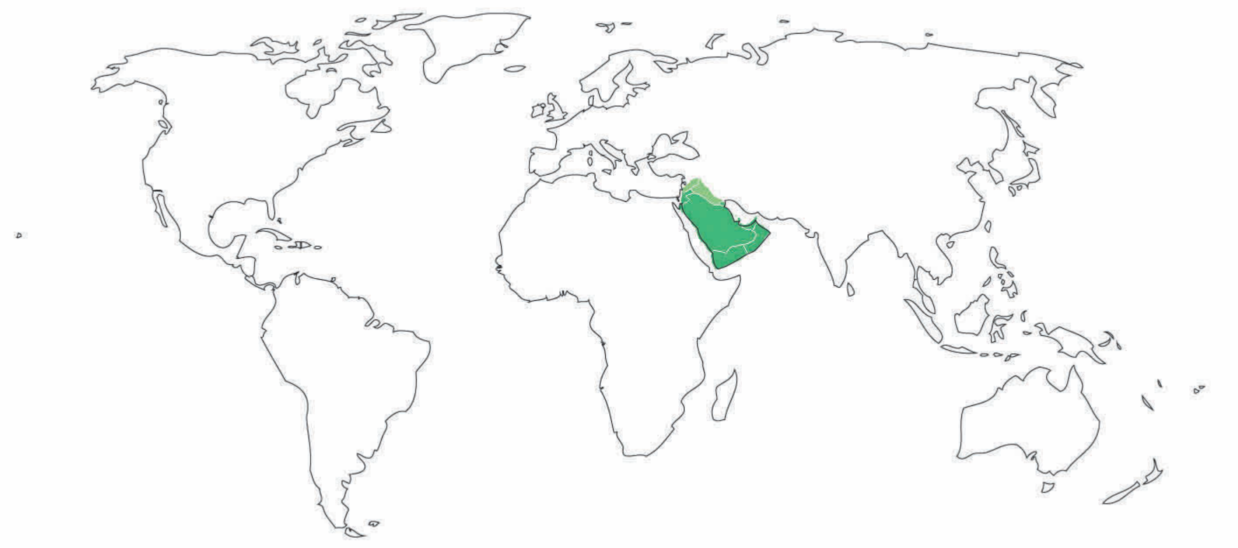


Figure 6→ Map of the Arabian Peninsula (dark green: political borders, light green geographical borders)

To overcome the challenges of resource depletion and emissions arising through the current development as stated above, with regard to the condition of the Gulf region, the author chooses the Sultanate of Oman as representative for settlement development in the desert region of the Arabian Peninsula. The climatic preconditions of the country can be subdivided into two different biomes: temperate grasslands, savannahs, and shrub land in the Hajar Mountains to the north representing the minor biome.

Deserts and xeric shrub lands are defined as having less than 250mm rainfall per year, including extreme temperature changes and a limited variety of species. On the eastern side of the Arabian Peninsula, politically comprised of the UAE and Oman, the climate is defined through high temperature (up to 50 degrees Celsius in July), high humidity, and low rainfall. Oman's Batinah coast (where most of the population live) receives an annual average rainfall of nearly 100 mm, mostly in winter. (WWF, 2013). Like in neighbouring countries of the GCC such as UAE, Saudi Arabia, Qatar, Bahrain and Kuwait, massive changes have been introduced through the exploration and export trade of hydro-carbon products around 40 years ago. These have resulted in a major impact on the morphology of cities, the ecology of the place, and the social coherence of communities.

Anthropogenic Biome Desert - Development and its Challenges:

In the meantime the growing population causes an increase of urbanisation, which impacts the natural systems through an overexploitation of the available resources in the specific ecological region. The Sultanate of Oman comprises a population of 3,090,150 (July 2013 est. Including foreign residents) with an annual population growth rate of 2.04% (2013 est.) (Statistics taken from *The world fact book*, 2013). Thereby a high trend of decaying decentralized interior villages shows in a growing figure of the urban population. 73% of the total population (in 2010) resided in urban sprawls of the Muscat governorate and the Batinah coast (General Census of Population, housing and Establishments project, Sultanate of Oman, 2010). The demographic distribution indicates a very 'young' country, as 55% of the population is under 20 years of age and 83% is under the age of 35. According to the World Bank fact book, Oman carried one cubic kilometre of renewable water resources compared to a freshwater withdrawal for domestic, industrial, and agricultural use of 1.36 cu km/yr in 2000. The prediction of the rising demand due to population, agriculture, industry, and trade will increase this number by 42% by 2020 to a total of 1.71 cu km/yr, noting that around 90% will be required for agricultural purposes (The World Bank Group, 2013).

The traditional source of water distribution, and equally the base for any oasis settlement on the Arabian Peninsula, has been either the *aflaj* (irrigation system) or a direct link to a well or spring. In the meantime, and to supply the demand on agriculture for instance in the Batinah region of Oman, mad-made wells of sub-ground fossil reservoirs and high energy consuming desalination plants have been introduced.

All agriculture in Oman is irrigated, and since 1970s the area under irrigation has increased from about 28,000 ha to 63,632 ha in 2005. Although 2.2 million ha are considered suitable for agriculture, groundwater is thought to be insufficient for most areas. At present, groundwater depletion has taken place, especially in coastal areas, leading to seawater intrusion and deterioration in the water quality. In the urbanized areas of current Oman, 85% of potable water is produced through high energy demanding desalination processes (both multi-stage flash evaporation and reverse osmosis technologies) (Ministry of Agriculture and Fisheries, Sultanate of Oman 2013). In total, per capita per day, an Omani citizen demands 181% of the available renewable water resources according to the World Bank Group.

The required amount of electricity produced 18.59 billion kWh (2010 est.) derives purely from gas or petroleum fossil fuels: 37% of the required energy is used for transportation, 24% for buildings, 35% for industry, and 4% for the agricultural sector. Major contributors to the annual energy use are residential buildings in Oman, which use around 450 kg of the oil equivalent per capita.

These factors result in carbon dioxide emissions of 55.2 million Mt (2010 est.) from consumption of energy. Compared to the world carbon emissions, Oman contributes 0.1% of the total whereas the UAE accounts for 0.49% and Saudi Arabia with 1.3% (The World Bank Group 2013).

The sudden detachment of the very close natural environment, which had traditionally been harvested very wisely in many aspects by the human settlers in the region, has necessitated a replacement of compensation strategies. What was before the utter integration into cycles of water, climatic factors, biodiversity, and socio-culture of the immediate surroundings, has now become detached through the introduction of artificial means to condition the daily life. Electrical pumps can harvest the water from deep wells, replacing the *aflaj* systems, which was used and maintained over thousands of years as a passive strategy in connecting to locally available resources. Electrical

power has replaced human and animal power as the driving force of agricultural processes. Electrical power also discontinues the method of wrapping a conditioning ‘third skin’ around the individual and the community by replacing the passive design strategies of settlements and buildings with the introduction of electronically powered climate conditioning apparatus. A ‘comfortable’ lifestyle, including less physical work and less strategic planning with the natural environment and the encapsulated climate controlled armaments of the built environment, has nourished the needs of the contemporary society for the majority of the inhabitants of the Sultanate of Oman. The economical revenue flow through hydrocarbon exports has never been higher in the country and has reached $71.78 billion in 2011 compared to $44.23 million in 1960 as per The World Bank Group (2013). The “wealth” is congruent with the demographics of the country: 2011 saw 2.846 million inhabitants on an area of 300000 square kilometres, in comparison with a figure of 456,000 inhabitants in 1950 with an annual growth rate prediction of 2.043% (2012 est. (CIA, 2013)).
The growing population maximizes demand on water, food and energy resources within the scarce environment of a desert. Current urban policies and governance encourages a peri-urban sprawl, resulting in mono-function land use that encourages high demands on infrastructure built up areas, degradation of biodiversity of the place, higher demands of energy, water, and mobility.
Further introductions to the case study environment of Oman will be given in Chapter →0500.

Shift in thinking cities

To again get into the game of being responsible for this ‘fragile craft’ of a resource scarce and climatically harsh environment of the Gulf region, this study aims to find ways for a paradigm shift of current tendencies of urban planning, design, and architecture. Hence a multi-level understanding of urban built environment as a system is used to examine the ‘foul’ organs of the current development nature.
Similar theories have been used in the 1960s by the Japanese Metabolism Movement where it is stated: ‘Metabolism is the name of the group, in which each member proposes further designs of our coming world through his concrete designs and illustrations. We regard human society as a vital process - a continuous development from atom to nebula. The reason why we use such a biological word, metabolism, is that we believe design and technology should be a denotation of human society. We are not going to accept metabolism as a natural process, but try to encourage active metabolic development of our society through our proposals.’ (Lin, 2010)
Where the Metabolists architectural mega structures inspired by organic biological growth processes stop at a purely formal metaphoric aspect of shape and form, this research extends the analysis of urban and architectural metabolic flows and their inherent strategies within natural occurring systems (see Chapter →0300) in order to sustain ecological resources, urban functions, human well-being and quality of life.

0120 The Quest for ‘Sustainability’

> *The environmental crisis is an outward manifestation of a crisis of mind and spirit. There could be no greater misconception of its meaning than to believe it to be concerned only with endangered wildlife, human-made ugliness, and pollution. These are part of it, but more importantly, the crisis is concerned with the kind of creatures we are and what we must become in order to survive (Lynton K. Caldwell in Dewitt, 2002, p.45).*

> *Aber da der unsere Theil der erben sich an Ersten durch viel Muehe und Unkosten hat offenbar machen lassen/da will nun Mangel vorfallen an Holz und Kohlen dieselbe gut zu machen: Wird derhalben die größte Kunst/Wissenschaft/Fleiß und Einrichtung hiesiger Lande darinnen beruhen / wie eine sothane Conservation und Anbau des Holtzes anzustellen / daß es eine continuierliche beständige und nachhaltende Nutzung gebe / weiln es eine unentberliche Sache ist / ohne welche das Land in seinem Esse (from latin: esse means being ; note of the author) nicht bleiben mag.*
> *Denngleich wie andere Laender und Koenigreiche / mit Getreyde / Viehe / Fischereyen / Schiffarthen/ und anderen von Gott gesegnet seyn / und dadaurch erhalten werden; also ist es allhier das Holz/ mit welchem das edle Kleinod dieser Lande der Berg-Bau nehmlich erhalten und die Erde zu gut gemacht/ und auch zu anderr Nothdurfft gebraucht wird.(Von Carlowitz, 1713, pp. 105f)*

From this quote of the 18th century silviculture (forestry) one of the most important factors of the burning topic of sustainable development in the 21st century becomes prevalent:
If the resources which are assigned especially for energy purposes (like in this example wood as energy carrier) seem to deplete, the human being reacts with plans of protecting those resources in order to ensure future use due to the human natures dependency on natural resources.
Satisfying our energy needs on the one hand and growing urbanisation rates on the other lets one rethink the meaning of sustainable utilization of resources. Examples of the past remain in the region of the Arabian Peninsula in oasis settlements that have endured the balance between human (energy) needs and strategies to sustain the available resources. However to follow the picture of an oasis in an urban setting now, the needs and demands would be romantic, but would not work due to the limitation of resources: the more people living in this system, the less resources they get. Or to put another way, the higher the comfort, the fewer who are able to survive. Both aspects, the amount of people and their comfort level - are the determinants of the built environment, which depends on the availability of resources in the overall natural system environment. If there are not enough resources, people, comfort, or both have to be adapted - or resources have to be

imported into the system from somewhere else. That is the reason for the attractiveness of fossil fuel as stored energy, which can be easily transformed back into energy. Therefore hydro-carbons were, and still are, very helpful to fill the gap between missing resources and population/comfort growth, between demand and supply. Millennia-long easily reachable fossil fuels were used on local levels. Then, since the beginning of oil extraction in the 1850s, and since an efficient transportation system via pipelines and ships was developed, the average oil consumption blew up to almost 5 barrels per year per capita (IEA, 2009) and the global population increased in the same time from one to seven billion (UN, 2013). Both developments have a tendency to rise further. In a fusion they explode even further and cause an exponential growing energy need. Forms of energy, which are based on other natural resources beyond fossil fuels, are thereby marginal and neglected.

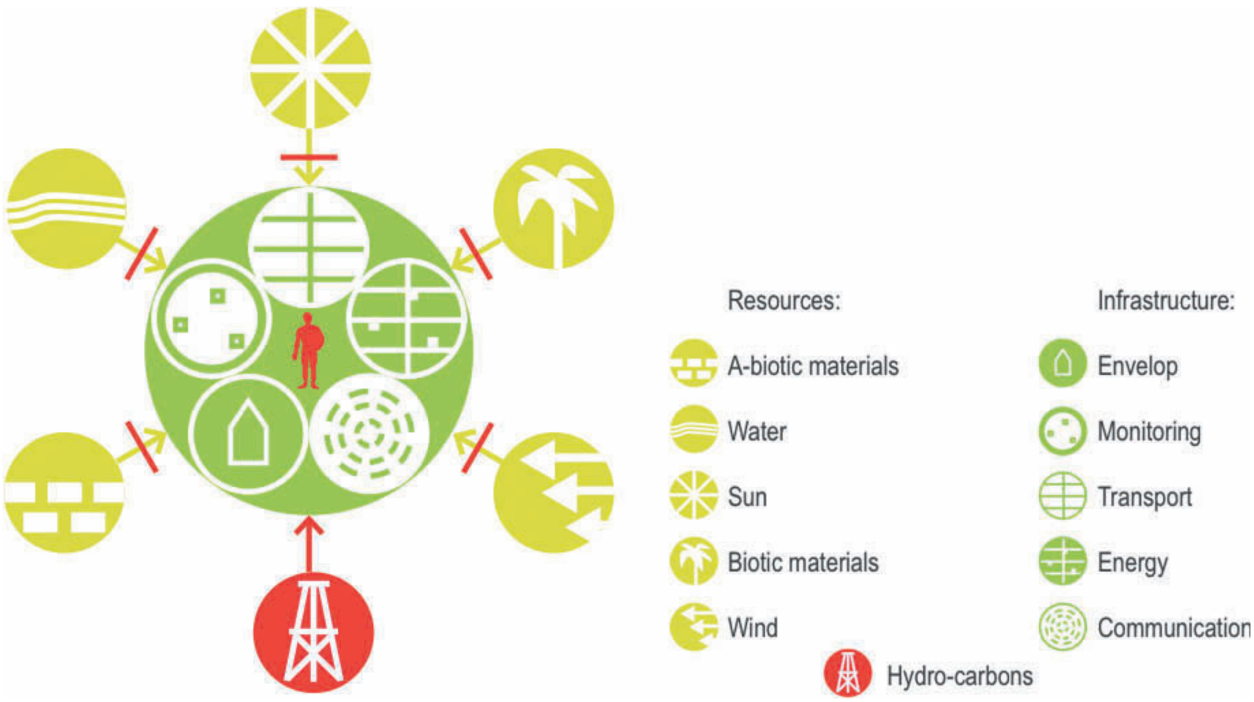


Figure 7→ Scheme of a present hydro-carbon city with destructed connection to natural resources

The satisfaction of energy needs is a question of national interests, which have produced and still produce crises. Starting with the first officially defined hydro-carbon war between Egypt and the Nabataeans 400 BC (Nissenbaum, 2013), innumerable wars have been caused since then, affecting innumerable victims (which is dramatic from a humanitarian perspective and a waste of energy from a system-thinking perspective). In terms of use of resources and pollution, the UN forecasted in 2011 a future “exceeding all possible measures of available resources and assessments of limits of the capacity to absorb impacts" (Lubin, 2011).

However the list of global diseases due to hydro-carbon based pollution is already quite long: Urban air pollution (Kenworthy and Laube, 2002), heat stress (United States Environment Protection Agency 2010), allergic diseases (World Allergy Organisation 2011) etc. already kill millions of people yearly.

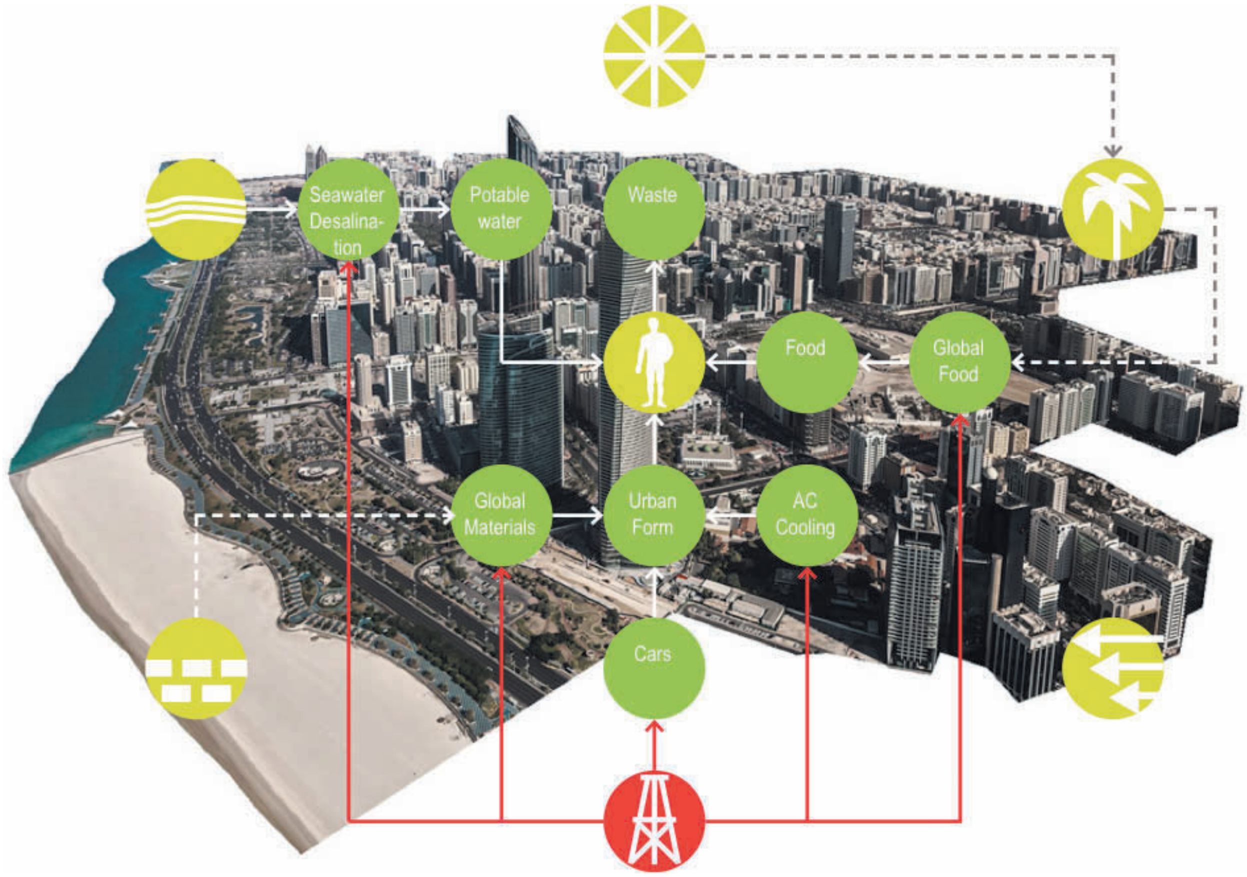


Figure 8→ Example of a hydro-carbon based urban system with external metabolism

Obviously, the effects of a change from local metabolism (e.g. of an oasis settlement) to carbon-based living in a globalised metabolism (See figures 7 and 8) are not only beneficial. But, at the same time, there is no way back to former times: Hydro-carbons are used for the desalination of seawater which is needed for a growing population in areas with almost no fresh water access. The creation and maintenance of cities for this population needs hydro-carbons, as well as the transport in or in-between. Additionally, a small minority of persons would like to (or could) live in this climate year-round without ACs. Moreover, local food products would be insufficient in terms of quantity and assortment. Therefore there is a general conflict between adaption to hydro-carbons and its deadly consequences.

Limits to Growth 1972

Consequences for the natural resources of the development of human made support structures, as warned by von Carlowitz in 1713, were later re-discovered in 1972 in a study initiated by the Club of Rome. The outcome of the computer modelling of exponential economic and population growth with finite resources was published by researchers from the MIT under the leadership of Jay Forrester with the title ‘Limits to growth’, financed by the Volkwagen Foundation (Volkswagenstiftung, 2013). This work was perceived as controversial by the public and was seen as the catalyst to start a critical future and environmental research.

The launch of the UNEP 1972

Briefly after this publication by the Club of Rome, the United Nations assembled in Stockholm for a conference about the preservation and enhancement of the human environment (UNEP, 1972). Following action undertaken as an outcome of the latter assembly, the United Nations Environment Program (UNEP) was established with the mission to provide global leadership and encouragement of partnerships in caring for the environment.

Our Common Future: World Commission on Environment and Development (WCED) or The Brundtland Commission 1983 and its report 1987 “Our common future”

The UN asked the Norwegian prime minister at the time to chair a special commission ‘Environment and Development Gro Harlem Brundtland’ to prepare a report asking for a definition of sustainable development and the "Process of preparation of the Environmental Perspective to the Year 2000 and Beyond" (The 1983 General Assembly Resolution 38/161). As a blue print to work in future on the issue of ‘sustainability’, the study of the Brundtland commission was finally approved and passed by the UN General Assembly on the 8th August 1987 as the Report of the World Commission on Environment and Development “Our common future”, which has congenitally influenced the Rio 1992 Earth Summit and subsequently all other earth summits by the UNCED and UNFCCC. Here the official definition of ‘Sustainable Development’ was established as:

> 3. Sustainable Development
>
> 27. Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainable development does imply limits - not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities. But technology and social organization can be both managed and improved to make way for a new era of economic growth. The Commission believes that widespread poverty is no longer inevitable. Poverty is not only an evil in itself, but sustainable development requires meeting the basic needs of all and extending to all the opportunity to

(UN, 1987, p.24)

Herewith, the foundations for an outlook onto sustainable development have been settled. Importantly for the built environment, emerging challenges have been examined as population and human resources, food security, species and ecosystems, energy, industry and urbanisation.

The solutions to deal with those challenges have been decided as: ‘getting at the sources; dealing with the effects; assessing global risks; making informed choices; providing the legal means; and investing in our future.’ (United Nations, 1987)

Further on, the scheme of sustainable development as defined by the UN was interpreted by the IUCN in the report: ‘The Future of Sustainability: Re-thinking Environment and Development in the Twenty-first Century’ and led into the well-known overlapping circles of: economy, environment, and society as stakeholders for sustainable development (see Figure 9).

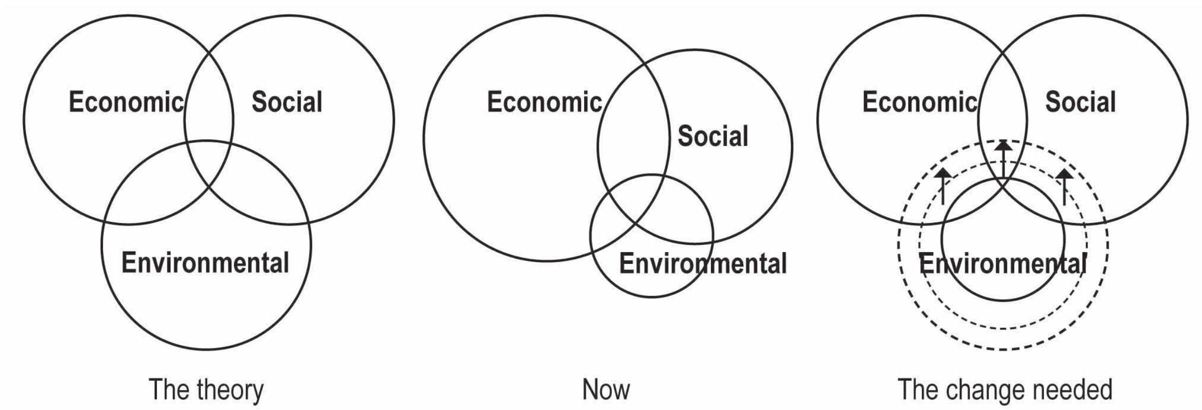


Figure 9→ Venn diagram of sustainable development by IUCN, 2006

Agenda 21 Rio Conference 1992

Established, again by the UN, to follow up the previous report ‘Our common future’ (1987) in order to proceed with specific action plans. The United Nations Conference on Environment and Development (UNCED) had several follow up meetings and continuations under the label ‘Earth Summit’. The nineteenth ‘Earth Summit’ session of the Conference of the Parties (COP 19) was held in November 2013 in Warsaw, Poland. Beyond the commitment for setting internationally binding emission reduction targets (Kyoto Protocol), other action areas for the built environment have been established as follows:

• UN Habitat and UNEP: Sustainable Cities and localizing Agenda 21 programs 1991

Other Action plans important for the built environment have further been laid out in the UN-Habitat’s Urban Environment Section, the Sustainable Cities Program (SCP). The fundamental objective of the SCP is to promote environmentally sustainable urban development. Since its inception in the early 1990’s, SCP has undergone two key phases with the following objectives:

- *Urban mobility*
- *Cultural heritage management and promotion of tourism*
- *Sustainable water management*
- *Access to urban services and social integration*
- *Revision of master plans*
- *Establishment of municipal environmental management system*
- *Strengthening of citizen participation in urban environment planning and management*

(UN Habitat, 2013)

• ‘Melbourne Principles’ for Sustainable Cities: Local Action 21 (Johannesburg Earth Summit) 2002

Finally in 2002 the Agenda 21 was broken down in an action meeting regarding sustainable cities where the so-called ‘Melbourne principles’ were issued. Ten principles frame the action areas to be appointed by decision-makers on a high level.

1. *Provide a long-term vision for cities based on: sustainability; intergenerational, social, economic and political equity; and their individuality.*
2. *Achieve long-term economic and social security.*
3. *Recognise the intrinsic value of biodiversity and natural ecosystems, and protect and restore them.*
4. *Enable communities to minimize their ecological footprint[4].*
5. *Build on the characteristics of ecosystems in the development and nurturing of healthy and sustainable cities.*
6. *Recognise and build on the distinctive characteristics of cities, including their human and cultural values, history and natural systems.*
7. *Empower people and foster participation.*
8. *Expand and enable cooperative networks to work towards a common, sustainable future.*
9. *Promote sustainable production and consumption, through appropriate use of environmentally sound technologies and effective demand management.*
10. *Enable continual improvement, based on accountability, transparency and good governance.*
    (UNEP & ICLEI, 2001)

• UNEP Sustainable Buildings and Climate Initiative (SBCI) 2008

Founded in 2008, the initiative acts as a subsidiary of UNEP to achieve policies and actions for the Rio +20 part of urbanisation, supporting sustainable buildings and construction practices through creating a common platform of stakeholders, developing tools and strategies for building practice policies, establishing baselines through measuring greenhouse gas (GHG) emissions, water and material consumption, and through the initiation of pilot projects (UNEP, 2012). The UNEP SBCI argues that buildings use about 40% of global energy, 25% of global water, 40% of global resources, and they emit approximately 1/3 of GHG emissions. The building sector is estimated to be worth 10% of global GDP (USD7.5 trillion) and employs 111 million people. Residential and commercial buildings consume approximately 60% of the world’s electricity. Buildings also offer the greatest potential for achieving significant GHG emission reductions, at least for cost, in devel-

[4] Definition ecological footprint: the impact of a person or community on the environment, expressed as the amount of land required to sustain their use of natural resources. (Oxford Dictionaries, 2013)

oped and developing countries. Furthermore, energy consumption in buildings can be reduced by 30 to 80% using proven and commercially available technologies.

The rise of 'green building' rating systems

With all of the intergovernmental policies and action areas laid out through the UNEP and Agenda 21 in the years following the establishment of the Agenda 21 protocol, private companies started initiatives to rate the sustainable efficiency of buildings through rating systems. At the time of writing, there are over 35 rating systems worldwide with a growing tendency towards their use. Although it has to be noted that all rating systems are licensed via private companies, apart from the compulsory Pearl rating system of Abu Dhabi's Estidama, which is upheld by the UAE government, but only applicable in the emirates (or one of the seven states of the federation) of Abu Dhabi. The United States was one of the first countries to implement a definition by the U.S. Environmental Protection Agency defining green building as the following:

'Green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation, and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as sustainable or high performance building' (U.S. Environmental Protection Agency, 2012).

Green buildings are therefore designed to reduce the overall impact of the built environment on human health and the natural environment, by reducing energy, water, and other biotic resources with the aim to reduce waste, pollution, and environmental degradation, in order to achieve and protect occupant health and improve employee productivity. Argued alongside Carlowitz' definition of 'sustainable' utilization of resources at the beginning of this chapter, the above definitions seem to be purely assessed from a human system's point of view, without questioning the available amount of resources or even the qualitative link of how those resources are deployed into the cycles of urban systems.

Examples of so far established 'green building' rating systems:

1990 BREEAM Building Research Establishment Environmental Assessment Method developed by the green building council | UK (private company).

1998 LEED Leadership in Energy and Environmental Design, developed by the green building council | US (private company).

2008 DGNB (Deutsche Gesellschaft fuer Nachhaltiges Bauen) German Sustainable Building Certificate| GER (private company).

2010 Pearl Rating System by Estidama, Urban Planning Council | Abu Dhabi | UAE (government).

While the above named rating systems vary in terms of evaluation performance metrics and certification processes, they all address the environmental, economic, and social aspects of the built environment through site characteristics, energy, water, and resource efficiency, and indoor environmental quality. Such rating systems have become the leading answer in the experts' debate on the measure of a building's 'sustainability'. Considering the growth of the number of certified building projects, the trend of a rising green industry can be predicted. Even a region like the arid hot desert of the Arab Islamic Middle East uses the US based LEED certification (in the same process and measures as used in the US, which formed under completely different environmental and socio-cultural circumstances) as an indicator of 'green building' in the desert.

The socio-cultural context and Sustainable Development

If the definition of green buildings is also concerned about human health and employee productivity, it is vital to also introduce the socio-cultural context of the built environment. The Arabian Peninsula community and their governments are Islamic ruled countries and their constitutions are based on *sharia*[5] law. Hence the following presents a glimpse of the quest of 'sustainability' within Islamic society: Al-Jayyousi (2012) describes four approaches to describe the combinations and relationships between people, environment, norms, and values in Islam:

> *a) Carrying capacity approach: based on being aware of the carrying capacity of the environment, which is referred to in Islam, as balance (Mizan).*
> *b) Ratio approach: based on an evaluation of a present situation under certain criteria and objectives including physical and human factors, which are referred to from an Islamic perspective as beauty (Ihsan).*
> *c) Socio-approach: takes into account people's interests and opinions in policy formulation and decision-making which is referred to as Arham, related to the human social capital and connectivity.*
> *d) Eco-approach: focuses on the intrinsic value of nature and the ecosystem services, which are referred to as Tasbeeh since all species are in a state of prayers (Tasbeeh).*
> *(Al-Jayyousi, 2012, pp. 13ff).*

In summary, those holistic principles shall enable all species, humans, and natural resources to be safeguarded against waste, depletion, and destruction. Other than the IUCN approach, Al Jayyousi does not include the economical level into the balance scheme between the carrying capacity of the natural environment and the human system. In this work the author shares in this perspective to reach a higher adaptability and viability of the built environment (→0200). Sustainable development will be approached later through the ecological toolkit of system connecting strategies

[5] Islamic canonical law, based on the teachings of the Koran and the traditions of the Prophet (Hadith and Sunna), prescribing both religious and secular duties and sometimes retributive penalties for law breaking. (Oxford Dictionaries, 2013)

(→0300), which can be defined as the coevolution of human and natural systems via integrated support systems (e.g. built environment, economy, governments, etc.).

Reaction of Architects and Urbanists

The output from architects, urban designers and planners regarding the quest for sustainable development over the last decade has various logos, names and approaches: e.g.The Network City, Peer-to-peer Urbanism, Biophilic Design, Biourbanism, Self-organizing Housing, Generative Codes, and Sustainable Architecture. Several attempts have been made to design, build and operate ‘sustainable’ cities.

What happened to the big sustainable cities of the future visions?

The Eden Project, by architect Nicholas Grimshaw, opened in Cornwall in 2003 and aimed to create a self-contained ecosystem; Dongtan and Huangbaiyu in China were both designed as visions and projected as carbon-lean cities. These projects have all, to some extent, failed to meet their goals. The Eden Project serves many worthwhile purposes - growing and preserving rare plant species, educating the public, demonstrating the principles behind maintaining a "spaceship Earth" - but it has not succeeded in being self-sufficient. Dongtan and Huangbaiyu have been criticized for failing to adhere to their own construction principles, in being delayed, and running over budget. The example of Dongtan as an ecologically sustainable city for half a million people off the coast of Shanghai was ambitious; a city without a landfill or cars, producing its own renewable electricity and generating zero carbon emissions (Arup Group Ltd., 2005).

The only ‘real’ succeeding developments that neglect to even call themselves eco-cities are initiatives, which can be found in Stockholm, Sweden, or in Freiburg/Vauban, Germany. Vauban’s holistic approach of community, planning, and governance lead to a sustainable establishment and the cooperation of integrative approaches, which are played out on a small scale a human perspective. With the goals of energy saving, new technology, and renewable energy sources, it has targeted to reduce CO_2 emissions to 25% below the 1992 level by 2010, to withdraw 10% of its energy needs from renewable resources, and to promote the transfer and synergies of technology and ideas. However, the challenges to meet those goals via PV alone are not feasible, so the city is looking at obtaining more energy from biomass and from wind power (Gaia, 2008).

The myth of Masdar city

Another approach for ‘eco-cities’ in the region of the Middle East is Masdar city, established in 2006. The public joint stock investment company ‘Mubadala’ explains its subsidiary developer company as: ‘…a commercially driven enterprise that operates to reach the broad boundaries of the renewable energy and sustainable technologies industry – thereby giving it the necessary scope to meet these challenges’ (Mubadala Development Company PJSC, 2013). The architect

Lord Norman Foster was commissioned to plan and develop the world's first zero-carbon and zero-waste city in Abu Dhabi, UAE, in the middle of the harsh environment of a hot arid desert. The masterplan (Foster and Partners, 2007 as shown in Figure 10) announced a 640-hectare low-rise, high-density project for 47,500 inhabitants which would operate without fossil fuelled vehicles. The introduction of wind and PV farms, plantations, and research fields promised to be entirely energy self-sufficient by 2020. Masdar reviewed their plans and, in 2011, issued a phasing plan where the first phase was scheduled for completion in 2015 and was expected to have 100 hectare of gross floor area that includes space for commercial, residential, retail, community, and the 'Masdar Institute', and would be home to 7,000 residents and 15,000 commuters.' In the meantime, as of 2013 the total site area shrank to a third of the initial planned area to 225 hectare. The built up areas remain on 3.6 hectare containing a massive steel-reinforced concrete car park and clusters of G+3 office, mixed-use, university, and food and beverage outlets. Apart from some live-in students, most staff and goods are imported on a daily basis.

A concentrated solar power plant serves the electricity supply during daylight on the west side. At night the development is fed by the gas turbine powered electrical grid. No farmland has been created yet and most of the construction materials to date consist of reinforced concrete, prefabricated concrete panels, steel, and glass. The water is still driven from the regional desalination plants. Solid wastes are subject to landfill areas in the desert. So far no waste-water treatment facility or gray/black water separation has been implemented. (All information has been retrieved from an interview with Mr. Rashid Al Araidi from Masdar, 13.10.2011 - considering that hardly any further development happened between 2011 and 2013, see Figures 11 and 12)

Figure 10→ Masdar city masterplan by Foster and Partners (2007)

Nicolai Ouroussoff of The New York Times argues that Masdar is ‘the crystallization of another global phenomenon: the growing division of the world into refined, high-end enclaves and vast formless ghettos where issues like sustainability have little immediate relevance.’ (Ouroussoff, 2010). The author would like to add the observation of the last three years and also the experience of having had guided tours through the mock-up of the development by the developer company, that ‘sustainability’ is used in this real estate project as a slogan to green-wash the project through symbols of renewable energy producing technology. So far no cycling of water and waste has been introduced. Lighting and power supply at night is mainly taken from the oil power plant grid of Abu Dhabi. Moreover, the stream of people working there consists of commuters that drive there every day. Apart from a few students at the Masdar Institute, most of the temporary inhabitants are commuters.

Figure 11→ Masdar city 2013 (south at the top satellite image[6])

[6] Google Earth 7.1. (2013) Abu Dhabi- Masdar City 24°25'58.52"N, 54°37'4.78"E. Accessed 23.11.2013. Available from: http://www.google.com/earth/

Figure 12→ Masdar city in 2013 (pink areas) mapped on initial masterplan from 2007 (south at the top)

Resulting challenges

The standstill and lack of further research and development, as had been announced in the initial vision, might undermine the quest for sustainable development and the investment driven property market on the other side. Despite the design approach of the urban fabric as low rise and high-density, the solution to solve the integration to the bio-climatic condition is pursued through technology only.

Many of the technologies proposed in this project (hydrogen power plant, gray water separation, PV, etc.) have never been tried or adapted to the dusty sand desert environment. One might also seriously question the approach of silicon based PV panels and their embedded energy 'costs' (harvesting of silicon, production of steel frames and glass panels, transportation) in comparison to their lifetime energy they can produce. Those PV panels might in reality turn out to cost more in energy that they will ever be able to produce. Technological solutions imported from countries and companies from other climate zones, might have to undergo urgent review and development to be suitable for the arid hot desert cases. However, such procedures underlie medium to long-term strategy plans that might not fit to the commercial turnout and amortising timeframes of purely investment driven companies, as is the case with Mubadala (see quote earlier).

The dilemma here shows exactly how the thinking in economic terms, in order to pursue state of the art models, depends on scientific research and development. Yet such endeavours, especially when looked at in the long run (over 20 years), are new to emerging young countries that have gained power through oil revenue fuelled export trade.
A culture of long term thinking, that looks at less economic growth and the risk of investing in non-revenue based research for the benefit of self-contained viability and tailor made solutions, is the biggest challenge in order to vaguely consider establishing 'sustainable' cities for a future of such 'young' regions.

Promising actions

An inspiring project therefore should be mentioned to ensure that careful planning considerations and long-term projected action plans can lead to feasible and promising results: The initiative of InnovationCity Ruhr | Model City Bottrop, formed in 2010.
This climate adaptive regional and urban redevelopment initiative is run by an interdisciplinary team of engineers, urban planners, scientists and further experts in order to realise a sustainable urban redevelopment of the pilot area of the previous heart of industrialisation landscape in Germany. The concrete aim is to cut the CO2 emissions by half and thus to increase the quality of life.[7]
In a bottom-up approach the goal is to reach the exit from nuclear and fossil-fuel energy by concepts like: Retrofitting of individual buildings with technological messuaerues (e.g. heat pumps, decentralised energy storage and management systems, local generation and onsumaoptn of energy). 125 different project have been proposed around action areas of living, working, mobility, energy and city with a clear focus on the ecivaisation of participating citizen via the slogan: 'Blauer Himmel. Gruene Stadt.' (blue sky (equivalent for the reduction of CO2 emissions), green city (equivalent for the advancement in the quality of urban life)).
The pilot region of Bottrop starts with an area of approximately 2500 ha and 70000 inhabitants to become a model also for international implementation of climate adaptive urban redevelopment measures.

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[7] ARGE IC Ruhr. (2012, 07 22). Masterplan Klimagerechter Stadtumbau fuer die InnovationCity Ruhr. Bottrop. (Masterplan for climate adaptive urban redevelopment of the Innovationcity Ruhr)

0130 Quantifying Qualities

"another earth, another sun, upon which, sheltered from the menace of the world of technology, we may subsist and sustain ourselves." (Heidegger, 1966, 179)

Urbanisation is changing nature's ecologies, where cities have become major consumers and contributors to changes of the natural system. It is altering the ecosphere through the anthropogenic human built environment. The contemporary term of sustainable urbanism includes issues of compact forms of residential development; mixed use centres with homes, jobs, services, and shopping in close proximity; integration of transportation and land use; and the reduction, recovery, reuse, and recycling of waste materials. Heat islands, greenhouse gas emissions, desertification, and water and waste pollution add to challenges where the accountable measures for solutions are suggested in terms of the output of an urban system. Where the flux of materials and energy rises globally and quantitative calculations lead to the notion to reduce those flows, collateral damages interconnected to the ecological system show that the approach of simply looking at reducing the damage might not be enough. To turn this thought around, the qualitative connection possibilities of the built environment, at the input and output stage of matter and energy throughput has to be explored before examining specific and quantitative solutions.

The current answer from the experts involved in the active making of the built environment to combat the occurring issues, as denoted by the (UNEP-GEO2), appears as a model of engineered technology that will save all the issues. As discussed previously, rating systems are mainly concerned with the consumption, emission, and reduction of resources. Those figures can then be compared worldwide (where it does not matter if the water consumed derived from a renewable fresh water well or from non-renewable fossil basins) and winners can be identified and awarded with medals. Methods like these do not take into account the existing local/regional biome or biosphere, or the socio-cultural circumstances at the place where buildings or urban environments are being rated.

In a climatically challenging and resource scarce environment like the desert of the Arabian Peninsula of the Middle East, it becomes apparent that a purely quantitative approach does not reflect the sensitive interplay of the ecosphere and human beings.

Professions dealing with urban infrastructures and building construction are still constituted, even in their education, on models of physics and mechanics, which were engineered during the industrialisation driven last centuries. Biologist Elizabet Sahtouris noted: "Western science is very rapidly changing toward an understanding of nature as alive, self-organizing, intelligent, conscious or sentient, and participatory at all levels. In this newer framework biological evolution is holistic, intelligent, and purposeful” (Sahtouris, 1999).

Contemporary science in other areas has heavily moved on into different scales of living systems (nano-, gene-, and bio-engineering, systems science, etc.)

Apparently, human kind is still stuck in the belief that engineers and other experts can invent technology to combat the issue of dis-connectivity from the ecological system of our environment. However, in order to sustain our *oikos* (household) we have to learn that to have and use technology, urbanism, architecture, communities, and all the introduction of support systems that we as human beings have made to compensate human comfort within the natural surroundings, is to directly link, connect, and morph those support elements into the logic of the Biosphere.

Hence the approach of purely quantifying needs, demands, supplies, wastes, emissions, and pollutions will not link the built environment to the natural system for a greater integrated approach to achieve sustainable development. An understanding of the ecological system and its inherent qualities must be explored to establish the synapses where man-made systems can be merged with ecological ones.

Ecology is not just a model to adhere to during the making of cities in the future, where the built environment needs to exceed its threshold of industrialized, modern, and post-modern cities in the conflict between machine and nature, and become connected via dynamic and holistic approaches. This is where quantitative rating systems are not enough to understand strategies of interconnectivity. We might be able to count synapses of a nerve system but more important, in terms of information exchange, are the axons in-between. The way in which those connectors interlink the synapses drives the quality of the overall system: the brain.

Looking at the built environment equally as a system, this work is concerned about the connections between occurring elements and flows, and moreover the interconnection qualities that are achieved.

In a reciprocal manner, to find out about the coherence of urbanism with ecology, it is necessary to identify the qualities of connections between inherent system elements and the strategies of connections behind those qualities. Only then can the success of architecture and urban environments in relation to their surroundings and determining ecological environment be evaluated. Qualities arise from the processes and patterns of relationships among the parts. Hence, we cannot understand the nature of complex systems such as organisms, ecosystems, societies, and economies, if we try to describe them in purely quantitative terms.

As Christopher Alexander states in “A City is not a tree” (1966) social and economic networks form complex interlinked patterns of urbanism that cannot be computed purely through linear dependencies. A systems view (→0300), which in itself only depicts parts of an overall system as a model, helps to qualitatively assess urban complexity.

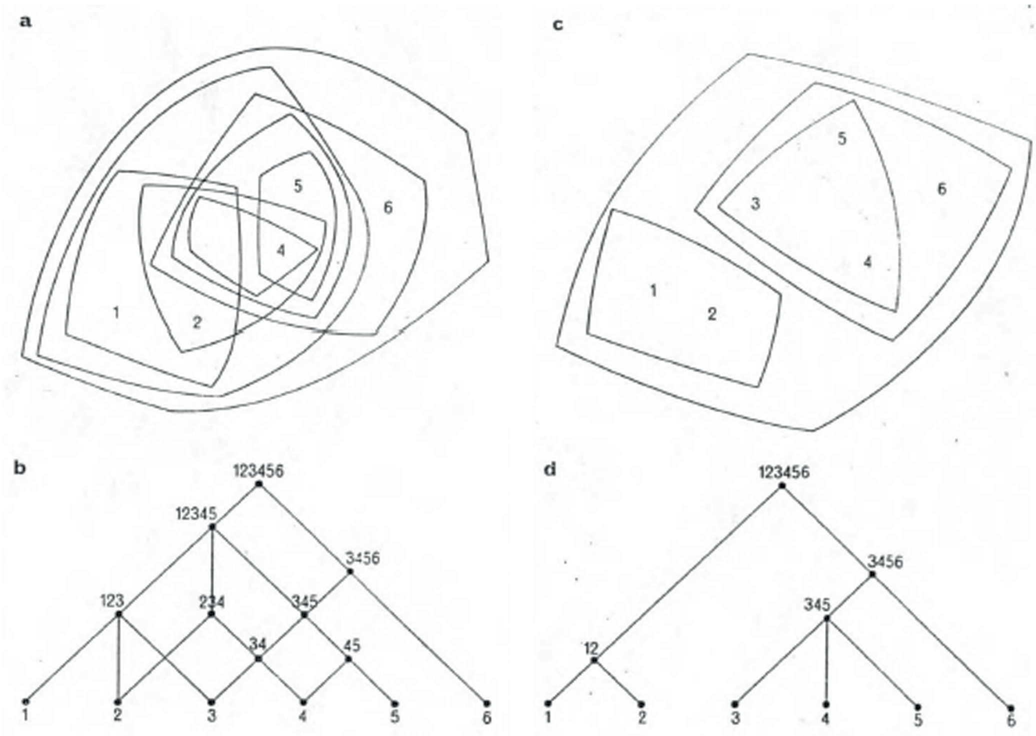

Figure 13→ A City is not a tree (Alexander, 1966)[8]

As depicted in Figure 13 ('A city is not a tree'), the semi lattice interconnectedness has different layers of elements with each other and the structural simplicity and vulnerability of a 'tree-like' structure. Ecological living systems work on the complex principles of semi-latticed structures. As Alexander also claims, a living city that is able to adequately respond to its ecospheric conditions of processes and resources needs to become a semi-lattice, where the emphasis no longer lies in the pure geometries of shapes and forms (e.g. design of urban and architectural shapes), but instead where the qualities of interdependencies of elements (flows and processes) make the system viable and thus 'sustainable'.

The quantitative approach of rating systems for buildings and cities in order to reach sustainable development considers solely the accounting of energy used, matter cycled, waste produced, emissions saved, or water cycled. Transferred to Alexander's tree diagram, only simple connections of two nodes or elements would be reached. Since all resources and energies that supply any human made environment are embedded in complex system structures of living systems, they have no choice but to respond and integrate to the available ecological systems in order to achieve environmentally responsive sustainable development of cities and architectures. This is where the ruling of man-made technology over nature has to change to a perspective of collaborating co-evolution with nature.

[8] Diagrams a and b depict semi lattice structures of living systems where different hierarchies are interconnected (gradually arisen 'natural' cities); whereas c and d explain a hierarchical structure where hierarchies are organized in a vertical manner (designed and planned 'artificial' cities).

0140 The Oasis as a system

> *"Water, water, water....There is no shortage of water in the desert but exactly the right amount , a perfect ratio of water to rock, water to sand, insuring that wide free open, generous spacing among plants and animals, homes and towns and cities, which makes the arid West so different from any other part of the nation. There is no lack of water here unless you try to establish a city where no city should be." (Abbey, 1990)*

To fulfil the quest of an ecologically adaptable built environment of cities and architecture in the deserts of the Middle East, it becomes necessary to look back into previous settlements that have endured over thousands of years. These models of 'urbanisation' in the midst of a resource scarce surrounding, without the operation of active technologies, can be found in traditional oases settlements prior to the introduction of hydrocarbons. Since some of those are still intact in the Sultanate of Oman, the author chose an oasis as the case study. Due to the high direct dependency on ecological resources and the bio-climatic adaptability, oasis settlements represent multi-faceted systems, which are routed in the ecoshere and the anthroposphere. An understanding of those settlements as a system model can give an indication for the organisation of semi-lattice structures and thereby the interconnectedness of all their components (further analysed in Chapter →0500).
As Nikos A. Salingaros describes in his 'Principle of Urban Structure' the scientific principles underlying the urban form surprisingly support traditional concepts of urban planning. He sees traditional cities as successful in terms of the evolved interconnections of form, components, and complex structure (Salingaros, 2005).
Looking back on the Arabian Peninsula around sixty years from now, prior to the economical wealth of oil and gas explorations that simultaneously brought a power supply through active technologies[9] introduced by industrialized nations, we find structures that have been built and maintained in socio-cultural compounds in the same shape and form over hundreds of years without any heavy amendments. Therefore, those settlements are a valuable indicator for human activities in the harsh and resource scarce environment of a desert through using passive technologies (here defined as non-electricity consuming technologies). Due to the lack of water (annual rainfall ranges between 40 and 100mm) being the prevalent climatic condition of the Sultanate of Oman, traditional settlements can be found mainly around or at sources of water. Given those climatic conditions, agriculture in Oman relies on man-made irrigation. Traditional farming systems have therefore

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[9] Active technologies use active mechanical systems to convert energy. Passive technologies use natural resources without active mechanical systems.

been developed in geological or topographic settings where water was accessible or easily reachable. (Luedeling and Buerkert, 2008)
In most of the cases, the built environment has been integrated into the farmland. Thus the following analysis will concentrate on settlements where the natural environment and the man-made infrastructure of agriculture and built environment go hand in hand. Socio-morphological changes are not considered since the new constitution of the country has been established from 1970 onwards, which has resulted in a massive decay of those decentralized settlements and a from-scratch urbanisation along the main industrial areas of Sohar and Muscat. Those settlements can be described as oases, which mean a fertile spot in a desert where water is found. The sources of water vary between three basic types. Oasis typologies are ranging from the underground rivers or aquifers of groundwater, to springs, where in most of the oasis settlements depend on the *aflaj* system of water irrigation. Ground water wells and artesian wells are mainly found in the flat areas of the Batinah Coast and in some submerged areas in the sand flats of Oman.
The given conditions of natural resources; namely water, prevailing winds, the solar impact, and biotic and abiotic materials have been used to create an advanced environment for the human being to survive in the harsh and resource scarce environment of the desert. All of these factors have been carefully considered and logically placed into passive design strategies, in order to engineer the natural given surrounding into a liveable entity (See Figure 14).
Traditional oasis systems in Oman are characterised as nucleated settlements that have been based on self-sustainable cycles and were adaptable to their prevailing conditions. Therefore such oasis systems have been autarkic over centuries. The sun would power the green plant life through photosynthesis, which again would be used as a source of energy, for agriculture and food, biomass, and construction products. The water of the irrigation systems would gradually turn from potable water into grey water and other wastewater for the irrigation of the farmland. Locally sourced materials like loam and rock would be used to create a compact and clustered urban infrastructure. In addition the waterproofing render to the buildings would be made out of loam and surrounding limestone, through a burning process with palm tree logs transformed into hydraulic plaster. The urban form is conscious not only of the available materiality and the construction methods thereof, but also considers the surrounding microclimatic environment of ventilation and shading as a precondition to adapt the shape and form of the architecture and clustered design. All the elements of this settlement have been perfectly interconnected with each other in a relationship of maximum benefit for all levels; purely through passive design strategies (see Figure 15).
As identified earlier, the current approach of hydro-carbon based compensation strategies enables the built environment to lead to global challenges that have been discussed in →0120. Again referring to Alexander’s model of semi-lattice system structures, oasis settlements as containers of

knowledge of adaption over centuries are a valuable basis to transfer ecologically integrated strategies for urban development in desert regions.

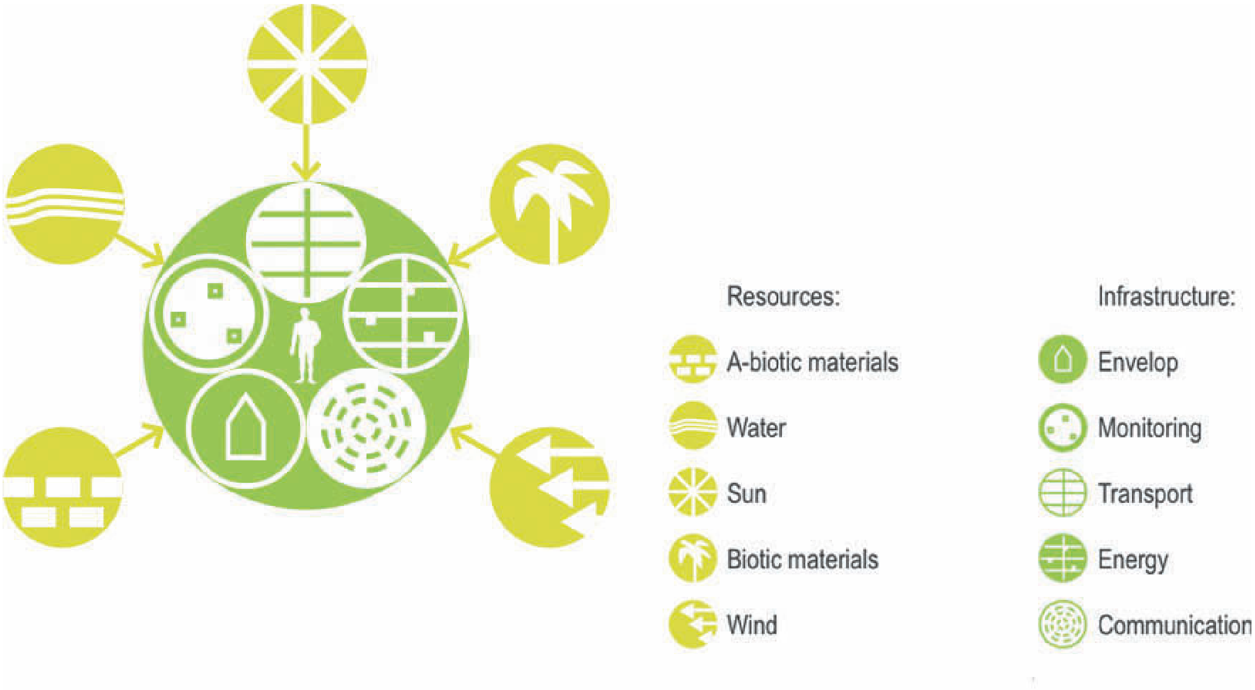


Figure 14→ Scheme of a past oasis settlements with high connections to natural resources

Figure 15→ Example oasis as non-hydro-carbon based system with integrative metabolism

0200 Hypothesis and Methodology

Based on the reflections of theories and backgrounds described in the previous chapter, the following major challenges resume the theoretical basis to formulate adequate research questions for this study:

• Current conditioning of the desert on the Arabian Peninsula depends solely on hydro-carbon power. Resulting emissions and waste contribute to the counter-principle of creating viable and thus bio-climatic adaptive cities. →0110 Conditioning the desert

• Although viable and adaptive settlements are referred to, ‘a city is not a tree’ (Alexander, 1966), yet ‘sustainable development’ on an urban and architectural scale is currently tackled through quantitative evaluations of non-connected branch like components. →0130 Quantifying Qualities

• Those quantitative rating systems, although developed for a different climate and cultural zone, are currently imported and used in the Middle Eastern cities in order to follow the trend of ‘sustainable development’. →0120 The quest for ‘sustainable development’

• Traditional strategies prior to oil-revenue driven urbanisation for the existence and effectiveness of human built environments are ignored and still could contribute as sophisticated knowledge to integrative approaches for urbanisation. →0140 The Oasis as a system.

Disconnectedness from tackling current pollution and re-growing resources issues in combination with a discontinuity from past via present to future of urban development in terms of the current trend of urbanisation, especially in the Middle East, steers towards an exponential growth of future challenge to producing sustainable living and integrated habitats.

Within the assumption that the built environment acts as a layer/membrane/skin between the human and the natural environment in order to compensate bio-climate conditions for the comfort of social-cultural context desires, the research questions to be asked are:

First, How is the built environment connected to complexities, hierarchies and orders of ecological and social systems? →0300 →0400

Second, How can traditional self-sustaining desert oasis settlement systems be transferred to future strategies of sustainable development for cities and architecture? →0500

Third, What general strategies can lead to a high level of adaptability and viability of the built environment in conjunction with integrating human and natural environment? →0600

Hypothesis

Links need to be established between the natural (Ecosphere), human (Anthroposphere) and built environment (Urban and architectural system). Then the built environment, as a support system (Figure 16), can enable viable correlations between the purposes of the human system in conjunction with the ecological complexities of the natural system.

A matrix (Bezugssystem) that references components of urbanism, architecture and technologies in conjunction with the natural and human environment can indicate semi-lattice interconnection possibilities. Through strategies of ecological system science such connections could contribute to achieve adaptable, viable and thus 'sustainable' interrelations between the anthroposphere, ecosphere and built environment. To be specific, it can be applied to hot arid desert biomes.

The processes of design and operation of urban and architectural aspects can hence be analyzed through a correlation model and yet, on the other hand, developed further to reach a higher interconnectivity between human and natural systems.

Learning from the eco-system inherent strategies and transferring them into qualitative links of flows and elements of the built environment, provides the change for cities and architectures to support human needs as re-generative organism within the ecological system. Hence principles of ecological systems create the foundation to define the strategies how to interrelate elements and flows in urban and architecture to natural and human resources. The goal of the correlation matrix is to enable adaptable and viable cities and architecture that are able to co-evolve as a cooperative sub-system with the inherent ecosphere and anthroposphere.

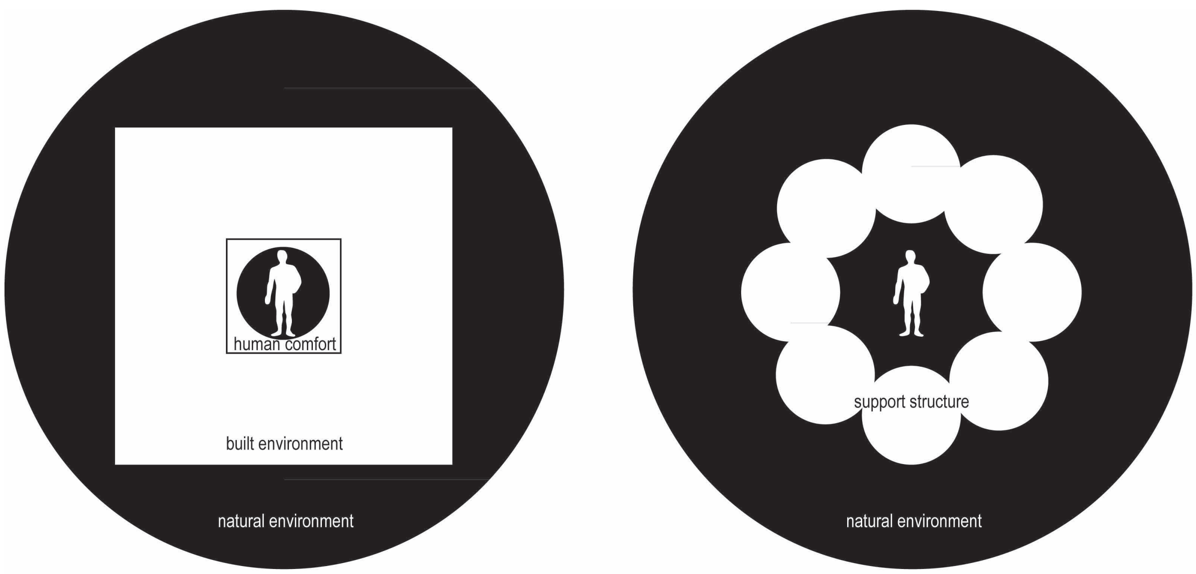


Figure 16→ Built environment as compensation structure and separator of natural and human environment (left) and built environment as support system interlinking natural and human environment (right)

Research Approaches

Since this research focuses on sustainable development of the built environment of an arid desert environment, a systems perspective may help to excavate the underlying complex interlinks of the support structure, built environment and their interdependencies from the natural and human environments.

Following this attempt to create a model of interconnectivity concerning the different environmental levels as discussed earlier, empirical research consisting of two qualitative case studies is analysed through ecological system strategies, which derive from the literature review of system theories for the built environment as supporting systems (not only the structure).

Therefore the methodological choices are based on three different empirical research areas:

1. Literature review based deductions: the literature review (in →0100) has shown that quantifying qualities in order to assess the 'sustainability of cities and/or architecture' might be limited. Further literature on (ecological) system science is used to analyse the prevalent factors of the surrounding environments and lastly to plug those into the factors of the built environment. The consideration of a holistic approach towards the built environment as a product and compensation layer in-between anthropogenic and natural environment leads to the review of system theories, principles and strategies. (→ 0300)
2. Field observation and the reconnaissance survey of case studies in Oman are based on analysis parameters as defined in chapter →0400:

   2.1. Case Study of pre-hydrocarbon revenue urbanism and architecture: research on 'Traditional Building Knowledge in Oman' was conducted in 2011 by the author and students during the 5th semester at the Faculty of Urban Planning and Architecture at the German University of Technology in Oman. The research was structured according to the following components:

   → The oral history of old building masters in the region focusing on building materials, technologies and regulations.

   → Case studies of selected traditional buildings in different regions of Oman.

   → An archive of historical documents related to the case studies.

   → Analyses of traditional planning and building regulation and the discussion of implementation into the 21st century thereof. (→ Appendix)

   The mission of this research and analysis was to revitalise knowledge that had evolved over thousands of years in Oman in order to transfer this knowledge into the future development of the country accordingly. (→ 0500)

In an exhibition (held in Muscat Oman in January 2012) the results of the initial research were presented and, at a conference, the content was discussed with the vision to analyse traditional building knowledge further in future scientific work.

For the purpose of this work, one example of a settlement in Ibra/Al Mansafah as part of the research above has been retrieved and will be discussed in urban and architectonical scales in Chapter →0510.

2.2. To compare the self-sustainable settlements of the past with those of the present developments in Oman, a case study of post-hydrocarbon revenue urbanism and architecture in the Muscat capital, Area, was carried out (→0520). Here, the residential area of Al Khoud is segregated as part of a university study called ‘My home is my castle’ (building analysis of contemporary residential villas in Oman) conducted in summer 2011 by the author with students during the 4th semester of the Faculty of Urban Planning and Architecture at the German University of Technology in Oman. (→ Appendix)

The case studies aim to investigate the phenomenon of underlying connection principles of the different environmental areas (nature, human and support infrastructure (urban and architectonical scale)).

3. Interview sampling of oral documents regarding urban comfort (→0430) in Muscat/Oman. (→Appendix)

The research and analysis of the different areas as described above lead finally into a concept of correlating layers of the built environment with the ones of the natural and human environment into a matrix of higher interconnectivity. Here the initial research questions should be integrated and answered through:

• Ecological understanding of urban and architectural environment so as to answer the question of ‘sustainably’ integrated cities and architecture.

• Environmental conditions impact on a morphological intelligence that impact on a new formal/spatial paradigm for architectural and urban design.

• Ecological strategies in urbanism and architecture link the performance capacity of material/natural and human systems with environmental conditions to a dynamic balance.

Argumentation logic inherent in the thesis

The main steps of this study’s methodology are as follows:

1. Review of system inherent principles and strategies. →0300
2. Identification of elements inherent in urban architecture as a built environment in relation to the natural and human environment →0400 based on a systems perspective as discovered in →0300.
3. Analysis of elements and flows in arid desert urbanism and architecture among cases studies in Oman in pre- and post-hydrocarbon-revenue periods. →0500

4. Comparison of case studies and identification of connection patterns and inherent strategies. →0530
5. Conceptualization of connection patterns - finding theoretical relationships among identified components and strategies as of 0300+0400+0500 in a correlation matrix (Bezugssytem).→0600
6. Discussion of the concept →0620 and recommendation of interconnectivity strategies between the natural, built and human environment. →0630
7. Learning from the developed results, implication possibilities and future research areas. →0700

Periphery of work

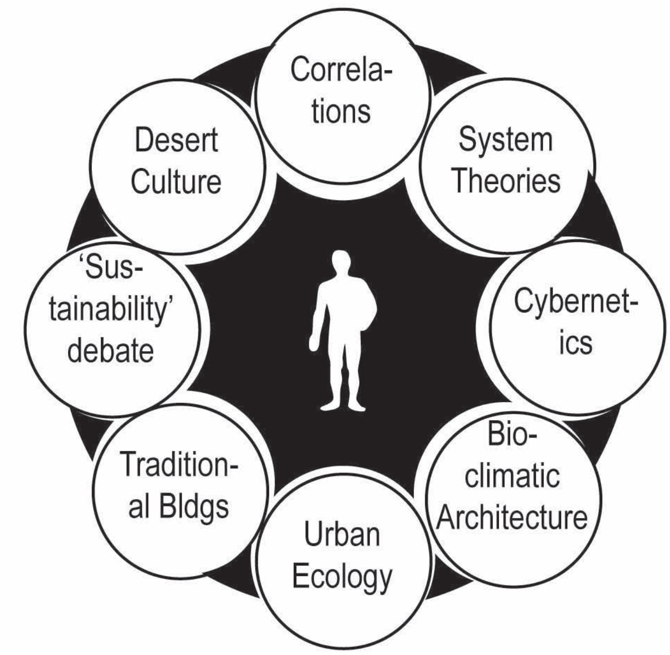


Figure 17→ Influence study areas for research

The macro scale finding of strategies to interrelate those different elements of the human, natural and built environment possesses the challenge of limiting itself to work related boundaries. The main focus lies in the correlation as described earlier according to Frederick John Kiesler (→0100). System theories (→0300) support the implication of urban ecology and its inherent input-out in terms of models of resource flows in the field of architecture and urban design/planning. Examples of theories and practices in architecture relating to a systems perspective can be found in the contemporary discussion and results of bio-mimicry, parametric design and bio-climatic architecture but also traditionally and localised in the desert environment of the Arabian peninsula. The entire mission aims to go beyond discussion of 'sustainability' as shown in Chapter →0100 and re-define ways or strategies that put means to the so widely proclaimed concept topic of sustainable development.

Figure 18 accumulates the input and outlines the essential influencing areas of the research. Based on the question of how an environmental responsive development can be introduced to cities and architectures, the author zooms out into the areas of systems thinking to learn principles that are inherent mainly in the logic of the ecosphere. As established by cybernetic approaches feedback mechanisms enable responsive metabolic systems. Urban systems also depend on flows (energy, resource, information). The current debate on depletion of resources demands a shift from a resource extracting linear way of approaching urbanisation to a circular approach. Output could also generate input into an urban system and hence the borders to rural resource-generating areas and purely built-up areas might fade or at least empower each other just like in traditional oasis systems. Analysis of contrary case studies is used to develop and test the theory of interconnectivity. Results lead into the general outlook of a conceptual reference system that combines ecological system strategies with the components and flows (energy, resource, information) of urbanism and architecture. Implementing the greater perspective for hoe to qualitatively integrate urban systems into natural and human systems, which they depend on.

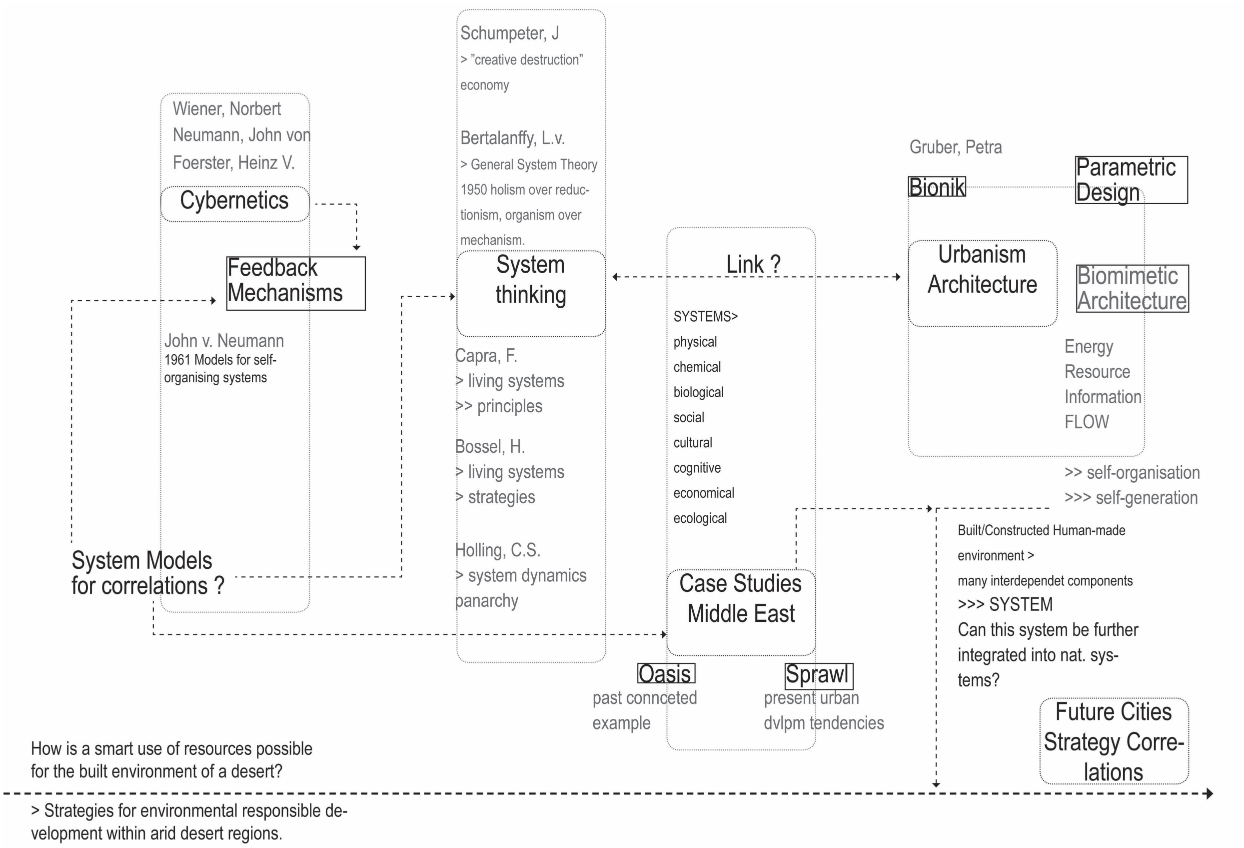


Figure 18→ Research periphery

Bearing in mind the aim of this research, the periphery of this work focuses on various concepts of creating sustainable development in the context of architecture and urbanism. Current design theories in parametric and bionic research already deal with determinants and their connection to each other, but there is a lack of general understanding of a holistic view of principles and hierarchies of living systems. Positioning this research on a macro scale where other approaches can be filled in, a systems' perspective can help to create and define ways or strategies on how energy, resources and information within the urban network of materialized flows can be connected. Not only the process of connection but also the quality of interrelation shall be transferred from the general knowledge of system theories into the field of the making of future cities, especially in the specific resource-scarce desert region of the Arabian peninsula. But the findings of chapter →0600 are also transferred into a global outlook, which has the potential to be generalized to other bio-climatic and socio-cultural region. This will be discussed in chapter →0700.

Setting the boundaries for this research

The challenge and the approach of the research lie in the clear definition of the focus especially whilst trying to propose universal validity. As will be discussed in the last chapter, what is explored here meets the goal of establishing greater dependencies rather than recipes for specific solutions. This is why the orders of the urban and architectural system pinpoint general groups or areas of elements, which can be filled in with specifics in a future approach to implementation. The research will explore connection qualities amongst identified elements and flows of the built environment and does not discuss any spatial implication (like the form, shape or design) of urban and architectural design. The more important are all of the flows deriving from the ecosphere, including their transformation technologies, which make those flows usable in the urban environment and the question as to how those flows can be redirected back into the built system.

Thinking perspective

> *"The debate about whether or not the whole can be predicted from the properties of the parts misses the point. Wholes produce unique combined effects, but many of these effects may be co-determined by the context and the interactions between the whole and its environment(s)." (Corning, 2002)*

The perspective of a multi-level understanding of cities and architecture examined in this research is based on an ecological approach of systems as models of resource in-and outputs, their feedback loops, system inherent elements, structure and environments.

Derived from the Greek words *oikos* (household) and *logikē (tekhnē)* (the art of reason), ecology[10] can be described as a systematic approach, where means that the system's inherent elements are

[10] This term was originally established as 'Oekologie' by the biologist Ernst Haeckel in 1866

connected together and form the system structure.

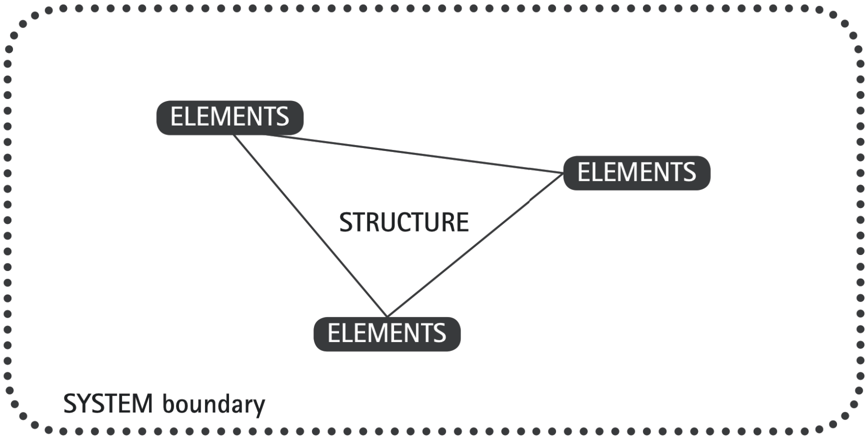


Figure 19 System description

Within the natural system of ecology, which includes biosphere (life), atmosphere (vapour), hydrosphere (water), lithosphere (stone) and pedosphere (soil), the anthropogenic environment forms yet another sub-system, the human system or anthroposphere. The evolutionary process in conditioning the human system within the overall ecological system of the planet, can be subdivided into various support systems like infrastructure, economic system, social system, individual development and government.

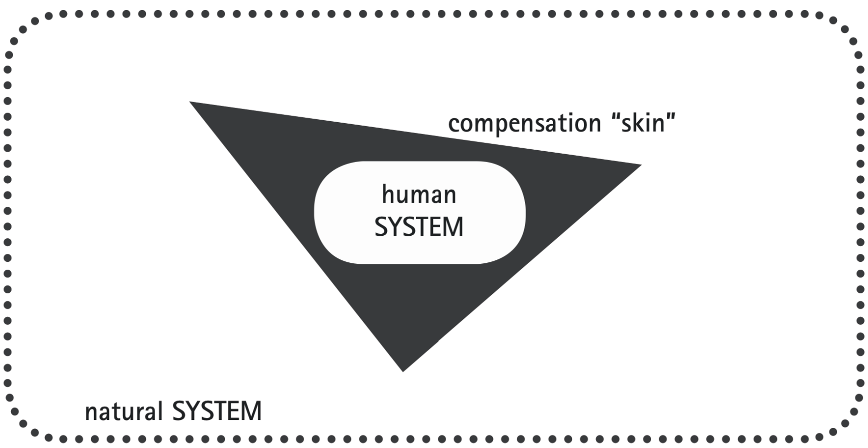


Figure 20 Compensation area between human and natural system

The concentration in this work lies in the infra-structural support system of the human system as 'conditioner' or compensation 'skin' between natural environmental resources and anthropogenic needs. Here it is described as a built environment and encompasses different scales from urban form to architecture and includes the necessary technological processes needed to convert energy and matter from the natural system in order to feed it into the urban and architectural environment.

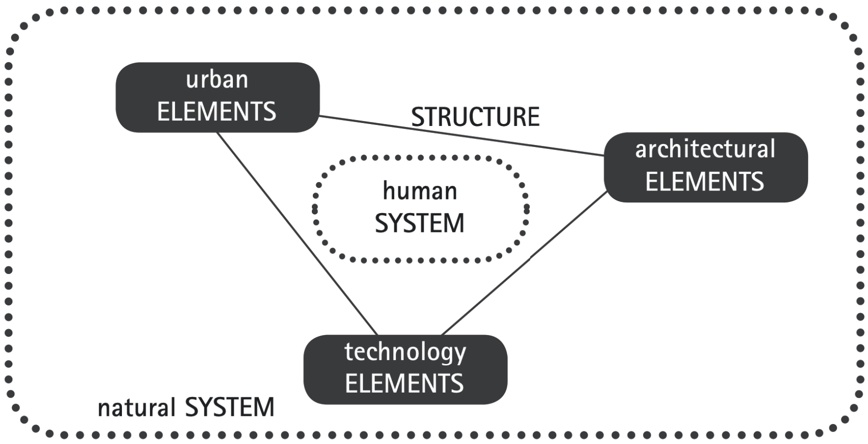


Figure 21 Structure of compensation areas

The built environment of urbanism and architecture is specifically hypothesized not as a self-governed act of man-made authorship on its functions, uses, aesthetics, social responsiveness, but as a human-influenced smart extenuation of the natural environment.

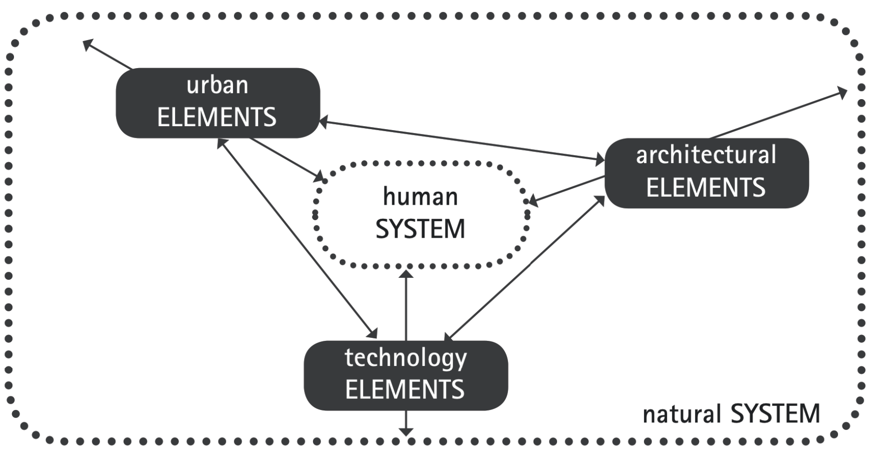
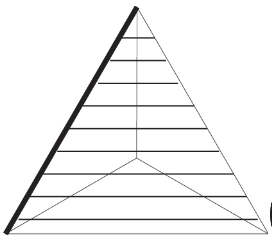


Figure 22 Strategies of adaptability for compensation areas

The focus here constitutes of strategic connections of elements and flows: settlements, cities, buildings, transportation and distribution as elements and flow-throughs comprising of the supply system (energy, water, food, goods, services, waste and disposal) that enable the necessary functions of a built environment: health services, communication and media, facilities for education and training, science, research and development, housing etc. Therefore the objection of this work to categorising architectural or urbanism elements, in order to interlink flows of matter, energy and information, leads to the necessity to find a commonly underlying organisational structure comprising the human, natural and built environment.
In the following chapter, the perspective will be adopted using system theories, which deploy the methodology of this work to establish an ecological toolkit of system connecting strategies for the question:

How can cities and architectures become a support system that has the properties required to co-evolve as a cooperative sub-system within the surrounding eco- and anthroposphere under the rules of ecology?



0300 Ecological Toolkit

"Unter Ökologie verstehen wir die gesamte Wissenschaft von den Beziehungen des Organismus zur umgebenden Aussenwelt, wozu wir im weitesten Sinne alle Existenzbedingungen rechnen können." (Haeckel, 1866, p.286)

Synopsis 0300

Ernst Haekel introduced the word Ökologie /Ecology for the first time in 1866 and defined it as a holistic science of interconnections of organisms to their environment. Beyond the pure content, which is driven by the scientific areas of taxonomy and mapping of elements of the environment, Haekel is here concerned about a process-orientated approach of organisms and the environment. The neologism of the word ecology in itself manifests the logic of the *oikos* (the Greek word for household). This logic as rationale of relationships can be understood as interplay between the inherent elements and their connection structure within a given boundary, or in other words ecology encounters environment as an interconnected system.

In order to find, analyse, understand and finally apply such interconnections in the field of architecture and urbanism, a systems perspective as methodological toolkit is chosen. The basics of system theories are outlined in → 0310. The main focus for this work lies on inherent principles for a living system → 0320, which will be further transferred into applicable strategies for the systematic making of a built environment (thus urbanism and architecture) that support linkages with its surrounding natural and human environment. → 0330 and → 0600

0310 System Theories

> *The fundamental thesis is that of architecture as a living, evolving thing. In a way this is evident. Our culture's striving towards civilization is manifested in the places, houses and cities that it creates. As well as providing a protective carapace, these structures also carry symbolic value, and can be seen as being continuous with and emerging from the life of those who inhabit the built environment. It is appropriate to stress an important cybernetic feature of the work; namely that unity is not uniformity, but is coherence and diversity admixed in collusion. (Gordon Pask)*[11]

The understanding of living and evolving systems, whether of the biosphere or of "automata, social networks or economic principles", appeared simultaneously in subjects like ecology, cybernetics, general systems theory or operations research in the 1950s. It has developed into a much broader and more differentiated approach to non-linear, cyclical networks of balanced dynamics, which characterise both biological life and complex artificial systems.

At the pulse of time: Eco-logy and system theories

An environmental understanding, the complex field of what surrounds us, has had an influence on the Zeitgeist of philosophers, artist, inventors of the time and therewith on the entire field of the man-made, or anthropogenic, environment. Those points of view of a socio-cultural condition on science speak the language of the time which is inherent in the evidence of cultural development, technologies and lastly in the built environment of urban planning, design and architecture. Looking at urbanism and architecture not as a materialized aspect of form, function and aesthetics but as a holistic network of flows and processes, still requires a shift of conventional thinking in terms of the built environment. Here the architect and urban planner need to be introduced to an ecological understanding of the built environment as an interconnected network of flows and elements that are bound together in a structure. This way of thinking has been followed since the 1930s when it was commonly formulated as systems thinking by biologists, psychologists, ecologists and economists. It has been used by several scholars of different disciplines like Ludwig von Bertalanffy in Biology to find the parameters of unifying sciences, Joseph Schumpeter for Business cycles to analyze Capitalist Processes in the field of economics or by J.W. Forrester to explore feed-back loop based system dynamics of physical and human systems.

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[11] Gordon Pask, 'Foreword', in John Frazer, An Evolutionary Architecture, Themes VII, Architectural Association Publications (London), 1995, p 6.

In the 1950s the rise of “general systems theory.” inspired especially by the writings of biologist Ludwig von Bertalanffy led to the formalisation of this interdisciplinary approach through the foundation of the Society for General Systems Research in 1956.[12] Here he postulated that the contemporary way of scientific research organised in isolated fractions of specialised units need to be changed into ‘dynamic wholeness’. Then the loose parts can be connected into a dynamic interaction of interdisciplinary cells (or life units) and form a dynamic science organism rather than fragmented organisations.
Different scientific disciplines like informatics, physics, biology, geography, mathematics, physiology, sociology, politics, psychology, ethnology, literature and philosophy now share topics and definitions of system theories, but this field has not become a discipline by itself. Therefore we cannot refer to one ‘system theory’ but an array of various theories.

Systems as simulation models

It also needs to be pointed out that the description of a system, the structure and the components thereof can only function as a model and therewith as an abstraction of reality and never as the reflection of an empirical truth. It can be rather taken as a model to simplify complex processes of occurring components, dynamics and mechanisms thereof through simulation.

The System Theories approach

Whilst the UN Declaration of Sustainable Development (→ 0120) through the Brundtland report focuses on the needs of a human population of the future and therefore products or quantities, the question remains how those quantities are embedded in a qualitative web of processes and thus how to solve connections in order to keep the resources and energy for the required needs flowing.
This can only be achieved though an integration of any kind of environments (in the case of this work the focus lies on the built environment in an urban and architectural scale) into ecological systems[13] of the natural environment.
Through a systems view we realize that objects themselves are networks of relationships, embedded in larger networks. To connect to natural systems, from which we as human beings and everything we produce are part of, it is necessary for us, to understand the underlying principles of natural systems. → 0320

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[12] Now: International Society for the Systems Sciences, see http://www.isss.org/world/

[13] Ecology = self-sustainable (natural) system based on cycles of energy, material (biotic and abiotic) and information. This work considers ecology in its etymological meaning of the oikos (greek for houshold) and logike (greek for the art of reason) not only applicable to the natural system but also as a general logic of ;households’ applicable to others systems like those inherent in the built and human environment.

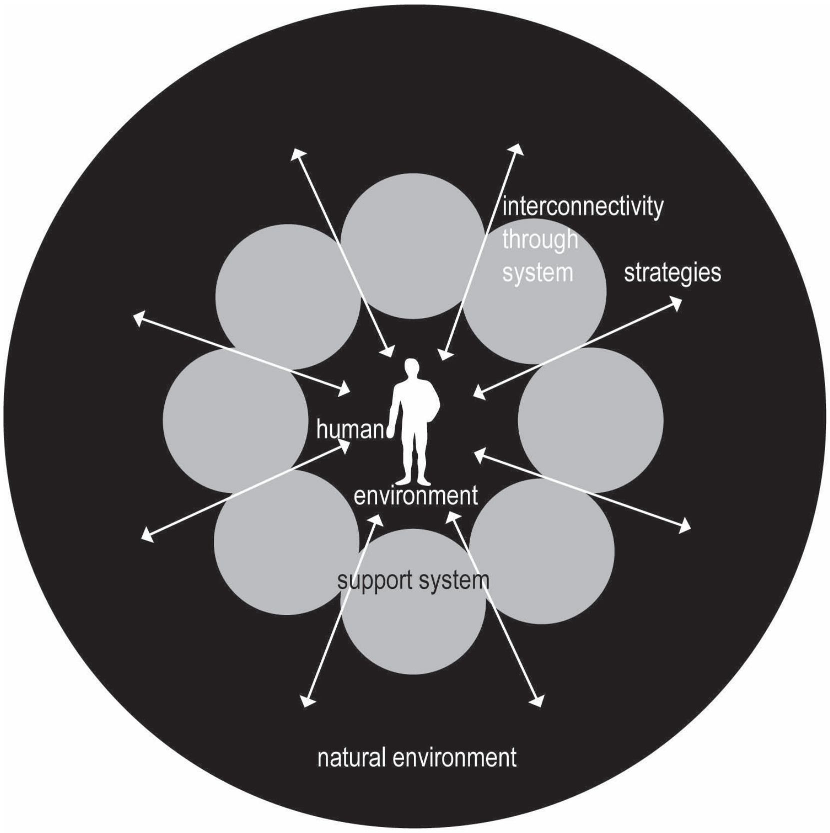

Figure 23→ Built environment as support system that links human and natural environment via interconnectivity strategies

An understanding of inherent principles in terms of the ecological system and hierarchies are fundamental to the quest of relating the built environment as a support system to the natural and human encompassing environment in order to provide a compensation 'skin' that acts as an interconnecting catalyst (Figure 23).

According to Donella Meadows's[14] system thinking theories, it is necessary to create a balancing model of flows of energy and materials (i.e. cyclical flows of resources), to avoid a reinforced exploitation of resources as part of living systems of nature and people. (Meadows, 2008)

In contrast, applied economic models show over the rise of trade that our current economic model is based on growth, which underlies the theory of reinforced systems, and thus growth. However, since living or ecological systems adhere to a limitation of resources, it becomes apparent that reinforcing systems cannot be accommodated in the debate of environmentally integrative systems.

[14] Who also co-authored the report: 'Limits to growth' in 1972, where global resources in conjunction to reinforcing cycles of consumption are simulated

Input equals Output + Entropy

Another influence on the understanding of the environment as an ecological network is given through the biologist H.T.Odum. He has established a formal mapping of resources and system inherent consumers and producers through his “system language” theory. In order to achieve the goal of comparing all of the different systems regarding their embodied energy, thermodynamically sound universal language had to be found. The diagram below describes the basic ecological cycle as per Odum’s system language:

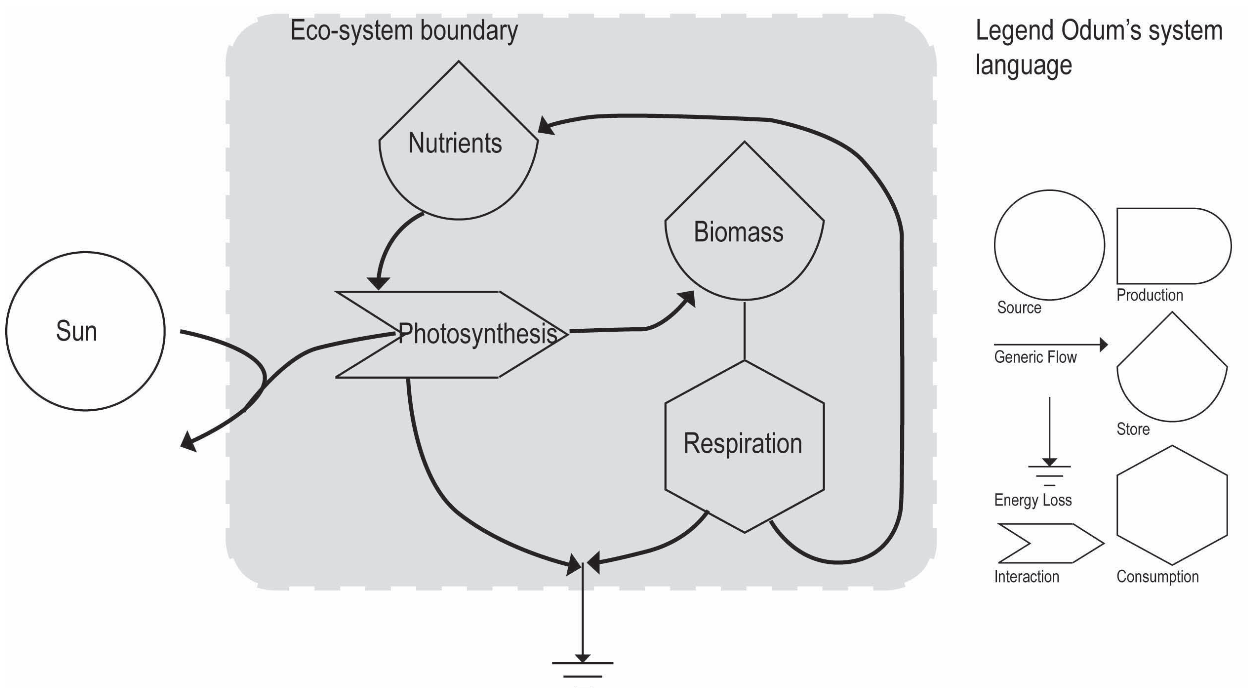

Figure 24→ Generalized ecosystem model based on Odum

Around the same time similar approaches have been undertaken by Buckminster Fuller (The world (peace) game) or Otto von Neurath (Iso-type project) to model ecological networks through graphical propositions.

The mapping of ecological systems shows that the functioning of a system, whether it is balancing (self-sustainable and hence cyclical[15]) or re-informing depends on the connection of the elements of the system. Those links and the underlying rules will be explored further through the understanding of viable living or ecological system inherent principles.

The combination of principles (→ 0320) and complexities (→ 0330) of ecological systems build the foundations needed to analyse the case studies in Oman (→ 0500) and to form strategies for interconnections of elements in the urban and architectural system (→ 0600).

[15] According to the Second Law of Thermodynamics, heat does not of itself pass from a cooler to a hotter body. Another, equivalent, formulation of the second law is that the entropy of a closed system can only increase. In Odums’ model this is indicated through the energy loss that always occurs when energy is being consumed or stored.

One further property of the understanding of system is viable to this work. The biologist HS Holling researches the timely factor of dynamics of systems. In his thesis of 'panarchy'[16] he determines the 'sustainability' of a system via the functioning of adaptive cycles. Those are dynamic and not fixed structures that always transform through four stages: from growth to collapse and from reorganisation to rapid growth.(Holling, 2001)
This theorem is comparable to the postulated system principle: 'dynamic balance' by Fritjof Capra (→ 0320) as will be shown later.

Why system theories in conjunction with the built environment?

> *'By seeing the ultimate aim of all our work as the regeneration and evolution of increasingly vital, viable and inspiriting places, we can reverse this loss (of our places). The good work we can do needs to be done in place, where we can experience ourselves as being*
> *connected with and relevant to the natural and social world in which we live, as playing a meaningful role as co-creators.' (Leaf Litter, 2006)*

Design strategies in the making of the built environment are driven by parameters that are considered in the respective era of surrounding circumstances and their conditions. During the Industrial Revolution new functions were proposed to the urban network and hence the strategy of design had to be amended to those conditions. Luis Sullivan's dictum of 'form follows function' had been a concept on how to tackle new urban activities, uses and programmes. Those programmes that have been incorporated on various scales can be seen as the flows, which are inherent in all instances of the built environment. Later the logic of functions were incorporated in automated machines and even into architectonical planning processes (Yona Friedman) and have been even praised as the new "Architekturmaschinen" (Konrad Wachsman in 1947) which has taken away the genius of the "Gesamtkunstwerk" artisan.
In a systems' perspective, flow is the exchange of materials, energy, people, plants, animals, and information. Those flows and the inherent system principles (as will be discussed in the following section) create patterns of relationships and result in structural orders. Also architectural patterns are the result of flow-based conditions and can be described as a process-form.
Architecture which mediates between the external processes of solar energy, on the one hand, and the climate + interior processes of human bioclimatic response, on the other hand, is here the interface or guiding membrane of flows. In general, the built environment relates to facts, forces and processes and these produce a platform of communication.

[16] The Panarchy model describes the adaptive and evolutionary nature of adaptive cycles that are nested one within each other across space and time scales.

The current world development commences in resources and energy scarcity, which is incongruent to the population growth and the demand on urbanisation. To link anthropogenic demand with available resources, an ecological thinking of the built environment is required. A function driven process seems not to tackle the issues, but a flow (of materials, energy and information) driven approach, which seeks to shape a process-form could tackle the issues. The current practice still tackles flows and processes as add-ons to structures that are still designed based upon an outdated urban programme driven century. Hence, an ecological systems approach could be:

> *Shape form to guide flow! (Lyle, 1994)*

With the introduction of Cedric Price's unrealised 'Fun palace' in 1961, the abstract contemplation world of cybernetics[17] as systems of processes became recognised in the world of architecture. Gordon Pask[18] and his system thinking proposed here to lift the difference between cybernetic design of architectonical spaces and to use cybernetics as tool itself to create space.

> *'The point I wish to establish is that nowadays there is a demand for system oriented thinking, whereas, in the past, there was only more or less esoteric desire for it.' (Vrachliotis, 2012, p.130)*

The trend of information technology driven architectonical spaces relate already to a system's thinking from the perspective of information flows, which generate structures.
A tendency towards appreciating architecture and urbanism as an ecologic network of itself and the resulting science on Urban Ecology and Urban Metabolism (more in urban system orders→ 0400) started in the recent years with the application of metabolic flows in architecture through the known Japanese group of 'Metabolists' around Kenzo Tange or Arata Isazaki in the 1960s.
Still influenced by the technological hype that man-made systems can solve all problems, the Metabolists architectural mega structures inspired by organic biological growth processes stop at a purely formal metaphoric aspect of shape and form. The analysis of urban metabolic flows as processes in order to sustain urban functions, human well-being and quality of life is only later explored later by Christopher Alexander (1977) in his seminal book 'A Pattern Language'. He pursued an associative networked system as patterns, which to enable designers to become 'pattern authors'. His work influenced computer science and engineering and therewith systemic design or parametric design as atomisation processes. Today parametric design enables digital fabrication of complex and irregular forms, which Charles Jencks describes as 'Non standard architecture'.

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[17] as defined by mathematician Norbert Wieners in his publication 'Cybernetics: Or Control and Communication in the Animal and the Machine.' 1948
[18] Pask was the inventor of intelligent cybernetic machines, which are based on feed-back loops.

In recent years the approach of the metabolist movement has evolved into different design theories for cities as ecosystems and 'green' buildings. For instance the concept of bionic architecture as movement for the design and construction of expressive buildings, whose borrows from natural (i.e. biological) forms and processes for layout and lines. On an urban layer an ecological understanding of environment can be noted through projects like: Ecovillage, Solar Village (Van der Ryn and Calthorpe, 1986), Environmental City, Green City, Sustainable City (Girardet, 1999; Nijkamp and Perrels, 1994; Gibbs, Longhurst, and Braithwaite, 1998), Eco-City (Roseland, 1997; Engwicht, 1992), Ecological City (OECD, 1995), Sustainable Urban Living (Girardet, 1992), Sustainable Community (Nozick, 1992), Sustainable Neighborhood (Rudin and Falk, 1999), and Living Machines (Todd and Todd, 1994).

Proposition of system thinking in this work

What makes the research here different from any design concept for Eco/Bio/Green or 'Sustainable' design of the urban or architectonical environment is the fact that the author does not give any instructions that can be quantitatively controlled, but rather provides an overview of different strategies that can act as qualitative decision tools in the process of designing, planning, implementing, amending and understanding the built environment.

In the infinite world of system thinking approaches, the author takes the position of being neither a specialised biologist, ecologist, mathematician, economist, planner etc., but rather focuses on the reasoning of how living or ecological systems are interlinked. Inspired by Frederick Vester's advocacy of the biocybernetic approach that every product, function and organisation 'should be compatible with the biology of man and nature' (Vester, 1988, p.412) a qualitative understanding of living system interconnections could act as multidimensional blueprint for the planning of the anthropogenic environment. Strategically positioned at the control interface of the built environment decisions, architects and urban designers are, in times of vanishing resources and climate change issues, predestined to using inherent strategies on a living system in order to transfer those into a comprehensive network of interconnected parts of architecture, technologies, infrastructure and urban design that adhere to the natural and human environment. Hence, the understanding of the built environment as an ecological system in itself comprising relations between buildings, urban fabric, and infrastructural entities is used to establish strategies and concepts how to interlink dynamically interdependent elements that built the structure. The following figures describe in general a system in its environment and the system of urbanism and architecture specific to this work.

Here in order to help flow guide the structure of the built environment as support system, principles of systems will be discussed in the next chapter.

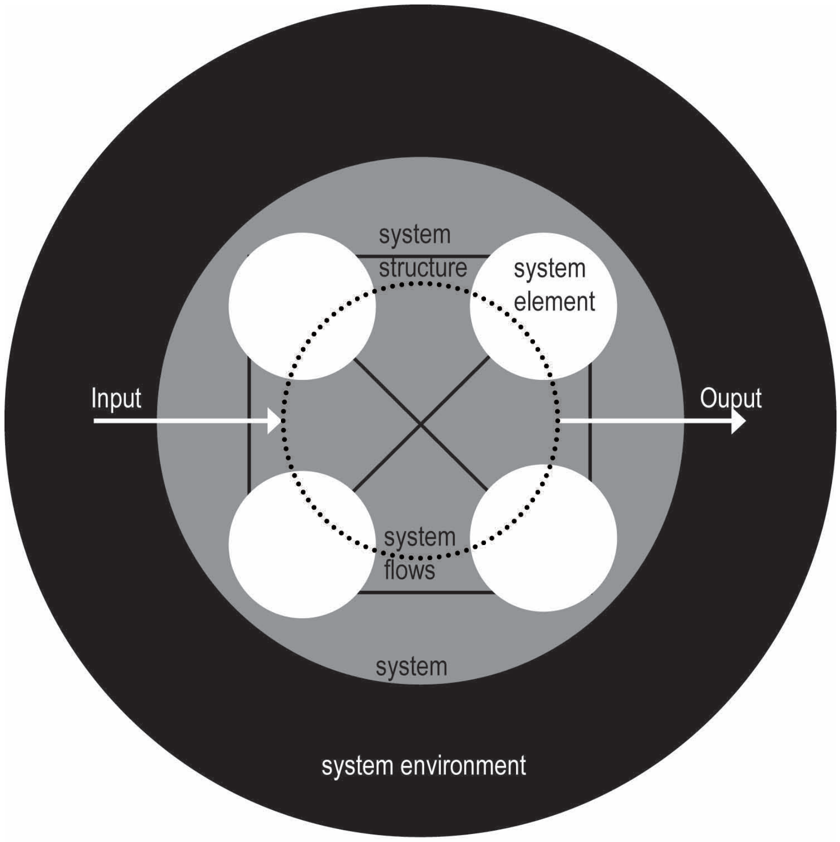

Figure 25→ System environment elements, structure, and flows

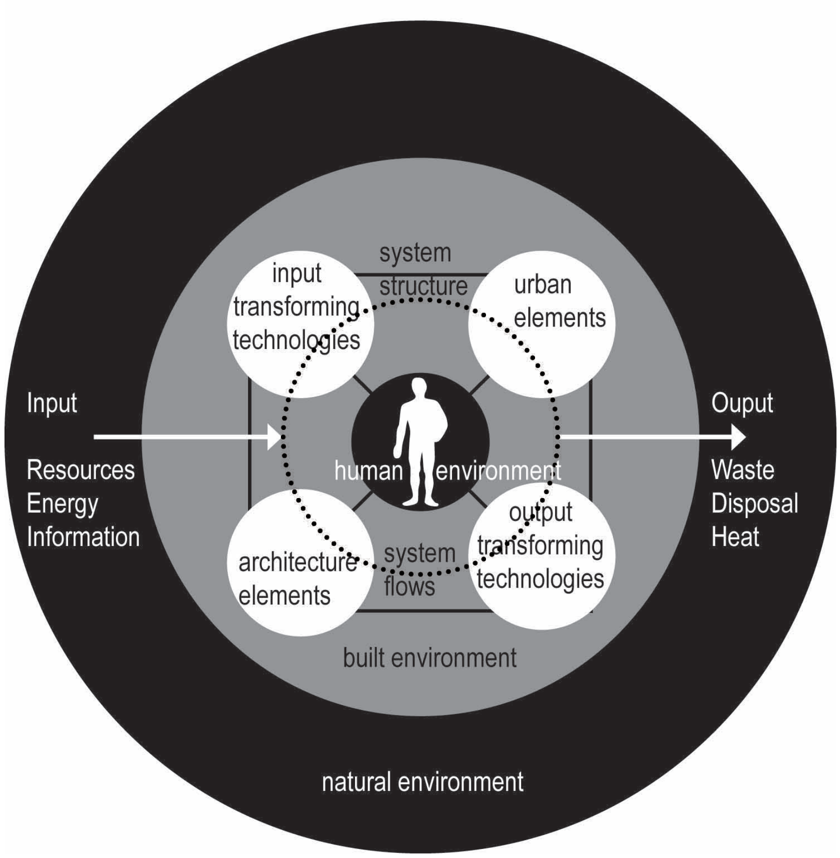

Figure 26→ The built environment as a system

0320 System principles

The principles of ecological systems are the foundation to create relationships using elements of integrated cities and architectures. Those principles compile the rules, which lie behind the interconnection of different elements of the built, nature and human environments. The way or concept how those relationships can be established will be discussed in → 0330 system strategies.

The physicist and 'Institute for ecoliteracy' founder Fritjof Capra (1994a) gives an overview of ecological system inherent principles:

> • Interdependence. *All members of an ecosystem are connected in a web of relationships in which all life processes depend on one another. The success of the whole depends on the success of its individual members, while the success of each member depends upon the success of the system as a whole.*
> • Diversity. *The stability of an ecosystem depends crucially on the degree of complexity of its networks of relationship; in other words, it dependes on the diversity of the ecosystem.*
> • Partnership*. All living members of an ecosystem are engaged in a subtle interplay of competition and cooperation, involving countless forms of partnership.*
> • Energy Flow. *Solar energy, transformed into chemical energy by the photosynthesis of green plants, drives all ecological cycles.*
> • Flexibility. *In their function as feedback loops, ecological cycles have a tendency to maintain themselves in a flexible state, characterised by interdependent fluctuations of their variables.*
> • Cycles. *The interdependencies among the members of an ecosystem involve the exchange of matter and energy in continual cycles. These ecological cycles function as feedback loops.*
> • Coevolution. *Most species in an ecosystem coevolve through interplay of creation and mutual adaptation. The creative reaching out into novelty is a fundamental property of life, manifest also in the process of development and learning.*
> • Sustainability. *The long-term survival (sustainability) of each species in an ecosystem depends on a limited resource base.*

At the later stage of this work those principles (as adapted in Figure 27) form the foundation of the formation of a correlation system of built, nature and human environment. (→ 0600)

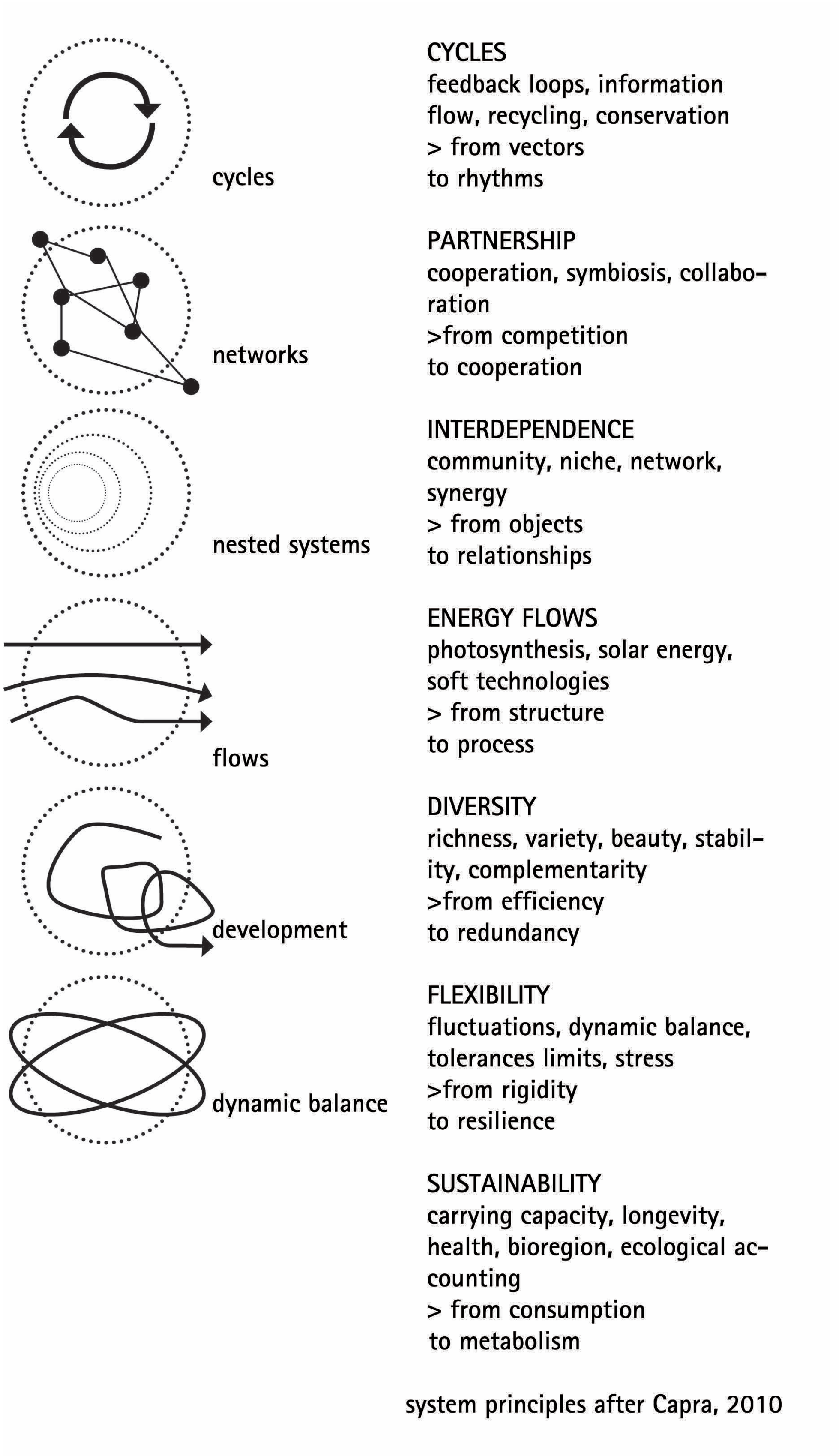

Figure 27→ adapted System Principles19

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19 Adapted from Capra (1994) and DeKay, M., & Bennett, S.(2011, p. 65)

Given the fact that those principles are inherent in any ecological system and that they therefore act as mankind's resource and energy provider through the natural environment, the current practice of designing a built environment can be examined.
Bill Reed provides a diagrammatic overview (Figure 28) of environmentally responsible design concepts in conjunction to energy consumption and their link to ecological systems.

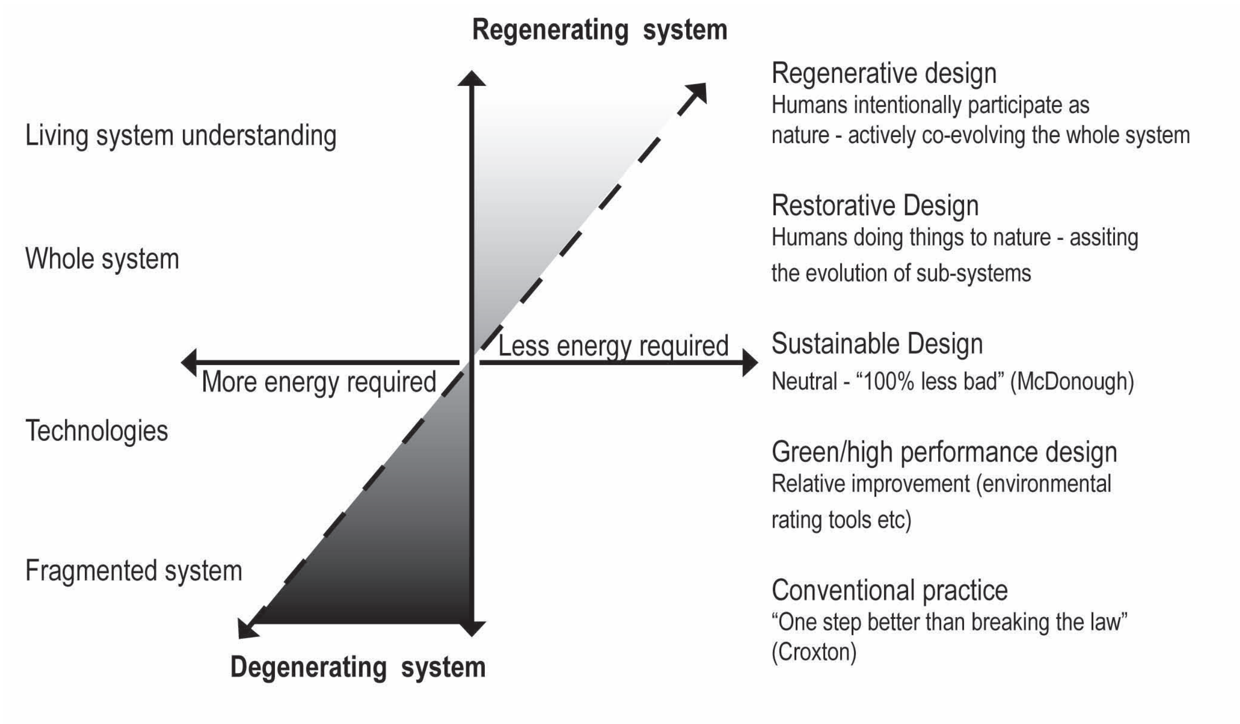


Figure 28→ Trajectory of environmentally responsible design based on Reed (2006)

Arguing from the point as stated in →0130, where technological solutions of green or high performance design just shifts the problems of resource and energy consumption somewhere else, this work will not consider anymore the steps of conventional practice in a model of correlations as identified in Chapter →0600.
The author is not concerned further about the nominations of design concepts and will hence classify the different approaches according to their levels of living systems' inherent principles. The highest level of which comprises the regeneration system. Here all of Capra's system principles are adhered to.
The diagram above shows that conventional practice, as well as the approaches of high performance design, through the reduction of energy, water and waste (mostly green building rating systems), the principle of networks and cycles are not implemented. At the highest level of regenerating systems, all system principles are applied through the understanding of living systems. Further, it is noteworthy to map the complexities and system inherent properties in order to establish strategies on how to achieve those system properties so that a man-made built environment can be connected to natural system networks.

System complexities

Beyond the principles of ecological or living systems, inherent system complexities shape a hierarchy from basic to conscious systems. The rationale of strategies upon which built environment can be connected to flows and resources of the natural system will be built up on those complexities. Interestingly such categories of complex networks do not only exist in the natural environment, but can also be correlated to the human environment. Different hierarchical needs of socio-cultural components relate directly to system hierarchies and properties. (→0410)

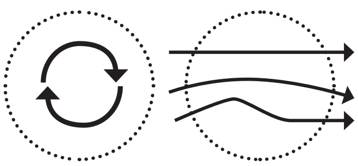
The higher the complexity, the more that interconnections between the system elements are necessary, and also the more viable in terms of co-evolution, regeneration and self-renewability is a system.

For the perspective of urban and architecture as systems, which have to link to the highly complex environment of natural systems, it is essential to achieve a high connectedness through the smart conceptualization of design, planning, implanting, analyzing and decision making.

The understanding of system hierarchies and complexities is therefore necessary to establish concrete strategies.

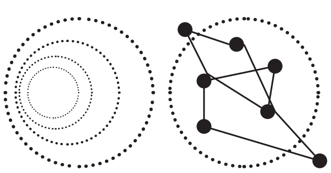
H. Bossel (2007, pp. 3-5) classifies eight levels of systems hierarchies:

1. ‘Static systems. The simplest possible system is inanimate and static”. The notion here of non-connected existence of elements without interaction with its surrounding nor having any through puts of services to the system is seen here as non applicable to urbanism and architecture within the debate of a higher connectivity to ecological systems.



2. ‘Metabolic Systems. The next level of complexity is represented by systems that require energy, material, or information throughputs for their existence”. Subsistence must be satisfied to ensure the viability of the system. Through flows are required to maintain the system.

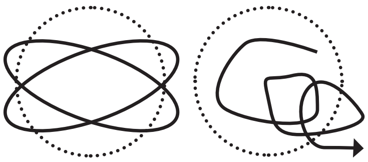
Since the introduction of technological services of principle hygiene standards into settlement schemes of civilization the static system of a shelter, hut or slum can be now considered as a metabolic system.



3. ‘Self-sustaining systems. The next level of system complexity is characterized by a system’s ability to sustain itself in its environment. This means in particular se-

curing necessary resources, protecting itself from adverse influences, and responding selectively ('intelligently') to environmental signals."

→ As described in Chapter →0100 in the quest for sustainability the set up of understanding our built environment as more than a metabolic system is crucial to the securing of resources. Hence, simple strategies of just keeping the metabolism running without taking into consideration this next level of complexity will be discussed later, which is a crucial point to connecting architecture and urban environment to the natural system.



4. 'Self-Organizing systems. On the next level of complexity, systems can change their rigid structure, parameters, or rules, to adapt to change in, and co-evolve with their environment. By changing themselves, these systems can respond flexibly and adaptively, even to previously unknown challenges."

→ Considered as the highest level of interconnectivity of human made support system and ecological system, here the line is drawn for the possible complexity, which a built environment could have.

All other levels are describing beings and their interactions or reflections, which lead to a psychological level that is not applicable to an architectural and urban environment.

5. 'Non-isolated systems. The existence of other systems in a system's environment will usually force it to modify its behaviour in some way. Co-existence means the fact that the system cannot act as if it existed in complete isolation."

→ Here we are leaving the realm of the built environment and focus more intensely on living systems which architecture and urban as support structures are part of but just in a supporting and compensating role. The following system categories are not being further examined as important to system attributes that are needed to connect built and natural systems.

6. 'Self-replicating systems. Special forms of self-organizing systems are self-replicating (autopoietic) systems that can generate systems of their own kind."

7. 'Sentient systems. Animals and humans can experience stress, pain and emotions as beings, which is an important part of their life and development."

8. 'Conscious systems. Conscious being s can reflect about their actions and their impacts, and they have to make conscious choices among alternatives."

0330 System Strategies

> *I believe that the whole idea about the natural environment has been turned on its head actually in a very strange way. For about a quarter of a century, people have been effect obsessed with saving the environment – which is of course a very sensible thing to do when it's being ravaged and destroyed.*
> *But the real problem is that we won't be OK, in terms of building or in terms of nature or anything else, until we learn how to make nature." (Christopher Alexander in an interview with Mehaffy, M. (2004))*

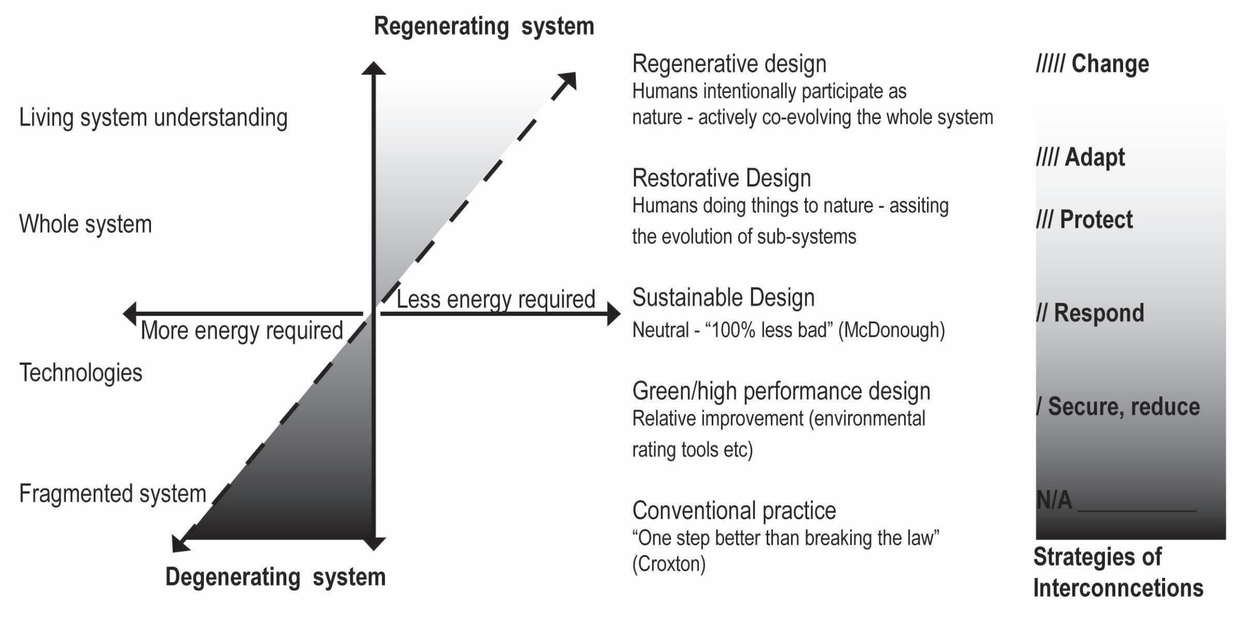


Figure 29→ Design practice (after Reed/Lyle) and proposed system strategies (based on Bossel's orientors)

For the designer, planner and decision-maker of environmentally highly integrated urbanism first of all the identification of system components or elements is important (→0400) and then the question how those are going to be connected.

After exploring the principles of ecological systems and, for this work, the underlying foundation of all interconnections to the built environment, the inherent strategies of ecological systems will further be examined. Those strategies can then be distilled and mapped onto the built environment as connector concepts between Biosphere and Anthroposphere.

Subsequent strategies are discussed on a general level in order to establish basic formulas that will later be applied in the case study analysis →0500 and further broken down into recommendations for application in → 0630.

Properties of system environments and their orientors[20]

H. Bossel claims that systems perceive their static and dynamic features of its environment only through physical flows (material, energy) and information flows from the environment.

If the built environment is now being treated according to the same systematic theory of natural system orders, it would mean that material, energy and information flows shape the built urban and architectural environment according to purpose. This purpose and henceforth the connections which a viable system undertakes to link to its environment are described in the following section.

The mathematician and system theoretician Hartmut Bossel defines six fundamental properties of system environments and their basic indicators or orientors of the system. (Bossel, 2007, pp. 183-187)

In what follows, the author converts those orientors (passive indicators) into active strategies, which can be applied as connecting tools for different system stages, levels and elements in general. Later they will be further considered for the conceptual correlation model (→0600).

1. *Normal environment state: The physical properties of different environments (sea, land, desert, arctic) enforce attention to an orientation of **existence**, causing organisms to avoid environments with which they are not compatible.*

The built environment as metabolic system hierarchy is based on feedback loops of existence. Hence the strategies inherent to this basic level of existence are subsistence-oriented strategies: For the natural resource streams, which are necessary for the built environment, the author resumes this first stage of system strategies:

Secure means in the subcategory of resource flows that resources are assured through reducing the throughput into the urban and architectural system (considering available resources especially water and the population growth in the region (as discussed in chapter 0100)).

As we will see later in Chapter →0400 most of the architectural rating systems apply this very basic strategy to flows of resources through a building or city.

Resulting strategies on static system level/subsistence for metabolic system levels:

0331 Secure	reduce

[20] Orientors is a description by H. Bossel, to indicate inherent system state properties via general concepts that can be interpreted according to applicable subject and allow quantitative comparison.

> 2. *Resource scarcity: resources (energy, matter, information) required for a system's survival are not immediately available when and where needed. This imposes an orientation of* ***effectiveness****, causing organisms and actors to develop effective and efficient means of using scarce resources.*

After essentially securing resources the next level is the one of responding to the scarce situation of abundant resources. Strategies that take into consideration the need to reuse, recycle and to conserve resources meet the objective of effectiveness. Mimicking how natural systems convert energy and matter into usable system flows is another tool, as well as in general responding also means that the system and its components stay flexible through resilient[21] connections.

Resulting strategies on the metabolic system level:

0332 Respond	reuse
	recycle
	conserve
	mimic
	flexibility
	resilience

> 3. *Variety: The diversity and variety of environments cause an orientation of* ***freedom of action****, allowing actors to respond selectively and appropriately to the multitude of environmental challenges.*

Allowing diversity and variety can be achieved through protecting the heterogeneity of system elements. This can be achieved through cultivating varieties, preserving efficiency of components, and to provide self-sufficient loops.

Resulting strategies on a self-sustaining system level:

0333 Protect	preserve
	efficiency
	cultivate
	self suffi-cient

[21] This word is derived from Latin: resilire- 'to leap back'

4. *The unpredictable variability of the environment imposes orientation of* ***security*** *(e.g. causing search for shelter and food storage).*

Shifts of environment inherent properties force systems to adapt to an amended form of flow of resources, energy and information. Hence a system can adapt through integration, self-regulation or the co-existence to other systems.

Resulting strategies on a self-sustaining system level:

0334 Adapt	integrate
	adapt
	self-regulation
	co-existence

5. *Eventual* ***change*** *in the environment causes an orientation of adaptability, enabling organisms, ecosystems and human organisations to cope with changing environments by change their own structure and process.*

After the strategy to adapt to surrounding conditions the last level for system connection strategies is that a change in environmental factors causes a change in the system. Here the built environment can react through massive interventions like manipulation that leads into co-evolving, re-generating and or self-renewing states.

Resulting strategies on self-organizing system level:

0335 Change	manipulate
	self-renewing
	co-evolution
	Re-generate

Higher hierarchies of system complexities (e.g. self-producing, re-producing) are only applicable to conscious, psychological environmental elements. Ergo, the author refrains from implementing those in the strategies of urban system orders. The highest possible level of complex processes inherent to the built environment is assumed here in this thesis to be the strategy group ‘change’.

Comparison of developed strategies and contemporary design concepts:

Design practices are, in what follows, interrelated with the developed strategies and also with the system principles. (See Figure 30)

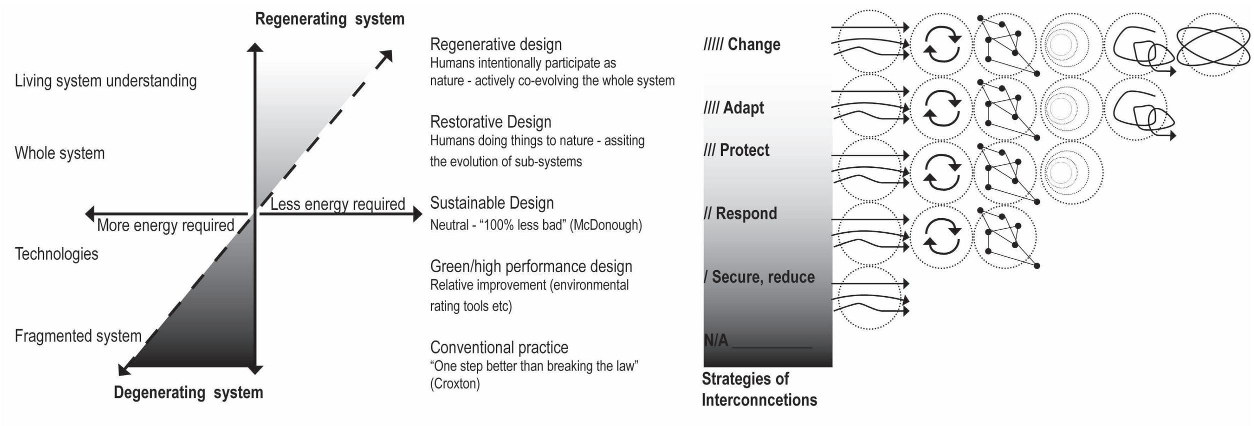


Figure 30→ Design practice (after Reed/Lyle), proposed system strategies (based on Bossel's orientors) and system principles (after Capra)

The conventional form of practice, which does not adhere to the simplest securing principle, does not give any consideration to the environmental impact and, hence, is not mentioned with any strategy that would connect it to an ecological system. Where secure Green Design practices appear on the first level of strategies and are mentioned, the main concept of minimising energy use, pollution and waste (termed 'less bad' design) (McDonough and Braungart, 2002) is congruent with the concept of reduction. But, in terms of system principles, reduction is not yet on the networking and cyclical level of systems. Therefore, it is only concerned with reducing flows but not reconnecting flows like it is subject of the metabolic next level. Here the so-called 'sustainable design' achieves a neutral environmental impact and maximum efficiency through applying system principles of flows, cycles and networks. Strategies like reuse, recycle, conserve, mimic, flexibility, and resilience around the strategic area of 'respond' can be applied to reach this goal.

'Protect' and 'Adapt' are strategies that can be related to the design practise of restorative design. Here, a higher system level for further development and the restoration of the ecosystem are areas of concern. They can be seen as a process of humans managing and manipulating ecosystems. (Couchman, 2007; Reed, 2007)

The last and most complex proposed strategy of 'change' can be compared to the approaches of regenerative development. Beyond integrating the human system into ecosystems, it focuses on creating and restoring capacity of ecosystems and bio-geological cycles to function without human management in an indefinite prospect. (Cole, Charest, and Schroeder 2006; Reed, 2007)

More examples of the defined system strategies in conjunction to contemporary design approaches for architecture, urban design and planning are shown in the table below:

Correlation	Strategies	Contemporary design concepts
Complexity groups	Associated terms	
/secure	reduce	Green design: Does not challenge current production methods or consumption patterns that have negative environmental impact (termed 'bad' design). Minimises energy use, pollution and waste (termed 'less bad' design). (McDonough and Braungart, 2002)
//respond	reuse	
	recycle	Cradle-to-cradle: Restores health of water/soil/air. Eliminates waste by using 100% biodegradable or 100% recyclable materials. Waste then becomes resource. This is termed 'waste equals food'. (McDonough and Braungart, 2002)
	conserve	
	mimic	Bio-inspired design: May result in regenerative, restorative, eco-efficient or conventional outcomes depending on the understanding of the design team. (Benyus, 1997; Pedersen Zari, 2008; Pedersen Zari and Storey, 2007)
	flexibility	
	resilience	
///protect	preserve	
	efficiency	
	cultivate	
	self-sufficient	
////adapt	integrate	Integrated approach: Co-ordination of planning and management activities associated with land use and land resources (including buildings, transport, urban design and infrastructure) to achieve additional value. May result in regenerative, restorative, eco-efficient or conventional outcomes. (United Nations Division for Sustainable Development, 2004)
	adapt	Ecological design: Design strategies may be modelled on ecosystems. (Reed, 2007)
	self-regulation	
	co-existence	
/////change	manipulate	
	self-renewing	
	co-evolution	
	re-generate	Regenerative development: Seeks to create or restore capacity of ecosystems and bio-geological cycles to function without human management.(Cole, Charest, and Schroeder, 2006; Reed, 2007)

Table 1→ Correlation Strategies in conjunction with contemporary design concepts

What can be so far read out of the toolkit is that, in order to solve the problems of managing and creating a human-made environment which is integrated to ecological systems, high connectivity strategies must be applied in all instances of flows of resources, energy and information. As a shift in the current practice of architecture and urban design with the goal to support comfort and life-style that serves the human environment, it is important to note that ecological system strategies applied in all areas encompassing our man-made environment are necessary tools to a viable and adaptable future that goes hand in hand with the capabilities of our planet.

0340 Findings

Sustainable development can be defined as the co-evolution of human and natural systems. The support system, specifically the built environment, as a conditioning layer between those two, has then the task to create dynamic balance, to enable development, flows, networks, cycles and partnerships. This is here approached through the methodological toolkit of system connecting strategies.

In this chapter, strategies and complexities on system inherent principles have been devised according to the hierarchy of a system approached. In the current practice of approaching sustainable development, it has been shown that applied strategies are still on the basic levels of interconnected systems that maintain existence and partially effectiveness through strategies like reducing, reusing and recycling. Table 2 below also shows that more strategies have to be implemented in terms of the connection between built, natural and human environment in order to achieve the goal of self-organising, coexisting structures via strategies of change.

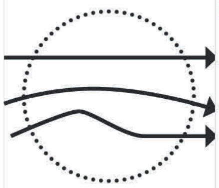
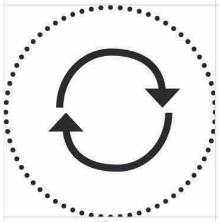
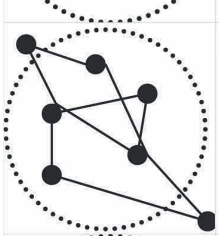
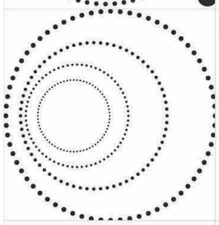
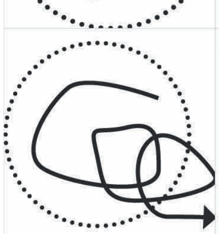
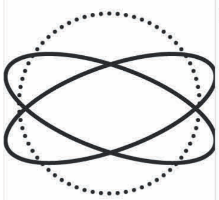
	system principles (after Capra 1994)	system complexities (after Bossel 2007)	system criterion (after Bossel 2007)	system strategies Correlation Model
	**flows**		existence	secure > reduce
	**cycles**	“Metabolic Systems	effectiveness	respond > reuse recycle
	**networks**			conserve mimic flexibility resilience
	**nested systems**	“Self-sustaining systems	security	protect > preserve efficiency cultivate self-sufficient
	**development**		adaptability	adapt > integrate adapt self-regulation co-existence
	**dynamic balance**	“Self-Organizing systems.	coexist	change > manipulate self-renewing co-evolution

Table 2→ System strategies according to system complexities and principles

0400 System Orders

Elements and Flows in the Human, Natural and Built Environment

> *We need to understand the functioning and the possibilities for changing specific systems of power, economic systems, transportation systems, and so on, which entail modes of resource use that are environmentally unsound. The fact that these various systems amalgamate in urban formations is an analytically distinct condition from the systems involved. The distinction between specific systems and background or contextual variables also helps us avoid the fallacy of seeing 'the city' as a container, and a bounded closed unit. In my research on cities and globalization, I instead conceptualize the city as a multiscalar system through which multiple highly specialized cross-border economic circuits circulate. This idea can be applied to cities and the environmental dynamic. In this case, the city is a multiscalar system through which multiple specific socio-ecological circuits traverse. It is not a closed system. Cities are amalgamations of multiple 'damage' circuits, 'restoration' circuits and policy circuits.*
> *(Sassen, 2009)*

0400 Synopsis

Nature and the built environment are not opposites or excluding concepts. In fact, they are interacting systems. The next step will be to outline a structure of inherent elements to the urban and architectural system, as well as for the human and natural system under the logic of living systems principles of organisation. The system strategies, which were discussed in the previous chapter, will help to build the concept as to how to connect those elements in the most integral way according to its components.

The formula of elements are then examined in the following two cases studies of the present planned sprawl and the organically grown past settlements in Oman, in order to retrieve the inherent connection qualities between those elements. Hence, the goal is to fix in a high level an ordering structure that, at the same time, leaves room for interpretation. Also, another challenge is to start this ordering structure knowing that scales in the built environment can be infinitely filled up in this ordering structure. Consequently, on an urban and architectural scale, there are the flows of infrastructural supply, which are not scalable but present and cyclical in all instances.

Components of the natural, human and built environment are identified to consequently trace the quality of connections between them. According to ecological system inherent principles a higher adaptive and hence viable built environment can be achieved if it interconnected to available resources, energy and information of nature and the anthropogenic surroundings.

The leading questions and resulting actions of the next chapters are:
• How to analyze the connectivity of scales of the built environment in conjunction to the human environment and the natural resources?
• How to find the strategies of connection that lead to higher adaptable and viable network of urban and architectural systems in the built environment?
→1. Identify system inherent components/ elements →0400
→2. Investigate the connections of the elements →0500 in specific case studies
→3. Associate strategies used for connecting elements. →0500 in specific case studies
→4. Correlate groups of components, flows and strategies into a model of Correlations →0600
→5. Make an ecologically sound urban system with the support of the Correlation model →future application of dissertation study.

According to a system's logic (→0300), the purpose or function of the system defines the structure to achieve effective in-and output of resources, energy and information through a system. Ergo, since the built environment provides human nature with its development and (co)evolution as a conscious living system, it is the work of the human system to define the purpose of the urban structure. At the same time, on the other hand, the urban structure depends on the resources and energies provided through the natural system. This implements those parts of the functions of the urban structure, which have to be adapted to the amount and availability of inputs of the natural environment due to decaying available resources and energies. For this task, cities and architectures in conjunction with energy and materials transforming technologies can serve as compensation Components/Elements on different scales in order to serve the human environment quests for comfort and development through the adapting to ecological cycles of natural environment.

0410 Human Environment

Social patterns and processes determine a human system through the interplay of demography, economy, institutions, culture, information and technology (UNU/IAS, 2003, p.10). When it comes to architecture and urban planning, human systems are mainly broken down into thermal human comfort levels. ISO thermal comfort standards are a common ground for expert engineers of technological building systems to implement thermal comfort through mathematical and physical equations.

Hence, human comfort is supposed to be measurable and controllable through right technologies that provide the perfect interior spatial climate according to fixed tables for the perfect-engineered climate.

The individual building encapsulates henceforth a disconnected conditioned climate bubble where an artificial interior spatial climate is provided for the needs of human comfort.

The input of natural resources, like light, air and water, into this segregated synthetically system is then compensated through technological equipment that ensures: electricity, lighting, water supply, water drainage, ventilation, cooling/heating and de-/humidification (air conditioning).

According to Klaus Daniels and Elizabeth Schwaiger in their work ‘Advanced building systems’ (2003), the comfortable thermal room temperature relates to 18-24 degrees Celsius, at 35-75% relative room humidity.

ASHRAE[22]’s thermal comfort table ranges between 20-27 degrees Celsius, at 20-60% relative room humidity. To reach those defined figures, current technological building systems and urban infrastructure technologies are geared to actively generate the envisioned throughputs.

Urban Comfort Muscat

The figures as stated above are mainly geared to serve temperate climate zones in Europe or North America. Hydro-carbon revenue in the Middle East has caused a massive influx in emergent cities on the Arabian Peninsula that are mainly served by ‘Western’[23] consultancies and contractors. They use building codes and conducts as per established systems of their own countries without adapting to utterly different climatic and cultural conditions. In order to verify the figures as per the

[22] ASHRAE The American Society of Heating, Refrigerating and Air-conditioning Engineers.
[23] “Western’ countries in the Middle East are understood as nations of Western-Europe and North America that went through the era of industrialization. Often they have an ex-colonial history in the region as well as the fact they are derived from a predominantly Christian belief system.

recognised standards as mentioned above, a survey about 'urban comfort' in Muscat has been conducted.[24]
Around 260 surveys were undertaken at a market area in Muscat, As Seeb, on a day of average temperature 37 degrees Celsius, lunch time, with 69% relative humidity.
Surveys were undertaken in three different spatial situations that are all not actively[25] air-conditioned:
shaded spaces, roofed spaces, and open spaces in a commercial area that is accessible to the public.
The pedestrians at the souk/market were questioned about their perception of temperature, ventilation, daylight, activity, humidity, Air-Conditioning (AC) habits, electrical light habits and their overall comfort feeling at the place at the time and given conditions.
Most of those interviewed in a roofed climate felt neutral to the temperature, expected more ventilation, considered that less day light would be necessary, were equally happy with walking and sitting, felt neutral to the relative humidity, would have the habit to turn down their AC's at home to 14 degrees Celsius, would seldom use electrical lighting and felt overall neutrally comfortable.

The situation was different when it came to the shaded spaces: temperatures were also perceived as too hot, more ventilation was desired, less daylight required, most of them were sitting, felt high humidity, would set their AC's at home to around 17 degrees, would also seldom use electrical lighting at home and felt overall neutrally comfortable.

Interviews in open spaces revealed that temperatures were perceived as too hot, ventilation as too little, daylight as too much. Whereas most of the interviewed people who were sitting also felt high humidity, were lenient towards AC's set to 17 degrees, more use of electrical light than the ones interviewed in other spaces and felt overall less comfortable.

The interesting outcome of those interviews lie in the discrepancy between the 'neutral' perception towards the individual comfort level in shaded and roofed areas at 37 degrees Celsius with 69% humidity and a desire of artificially cooling of spaces to 14 or 17 degrees on the other side.
Hence the desire of cooler spaces does not necessarily depend on the human need but rather on a desire relying on technological opportunities.
Another interesting fact that reflects very well the socio-cultural condition of the Arab-Islamic community on the Arabian Peninsula is that natural daylight is in most of the cases not desired. In a

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[24] See the Appendix for "Urban comfort in Muscat' interview templates and interview results
[25] i.e. technologically (and hence energy consuming) supported

country were the sun irradiates almost everyday for around 12 hours a day, it might become clear why a limited use in the built environment might reflect their desire for shelter.
This insight might have the opportunity to give a new understanding for the designing of facades, since openings for day lighting is not required or, at least, is limited and therewith contrary to expectations of a Western European perception of openings and their relation to interior spaces.

For the built environment it becomes apparent that the functions that architecture and urbanism have are purely correlated to the human conditioning of life that encompasses many levels of the human system beyond the technological and physical nature of the so called human comfort.
Many 'sustainable' city approaches claim to create quality of life through rating systems or 'recipes' like the green city index that can be fulfilled through the application of solely quantitative technological aspects. (→0120)

However, this work investigates system inherent in principles and connections in order to be able to consider the qualitative adaptability of the built environment as a support structure to the surrounding natural and human environments.
Because of that an understanding of the anthropogenic environment[26] entails understanding of a system according to previously categorised principles and complexities.[27] (→0300)

Human System

'Human scale development' relates to psychological, social needs, lifestyles, social systems and ecosystems. In the following section, basic indicators and elements are explored that contribute to a human scale development as inter-relation, inter-active, inter-connected system structure.
Under the consideration of theories of psychological social needs (Max Neef, 1991), cultural theory lifestyle (Thompson et al., 1990) social system concepts (Luhmann, 1997) and ecosystem properties (Mueller and Fath, 1998), Bossel establishes basic indicators and complexity levels for the human systems (Bossel, 2007, Those indicators of human systems are directly correlated to system principles and complexities as discussed in →0320 and →0330. Moreover they demonstrate again a general (recursive) scheme for identifying indicators of viability.
As postulated by Bossel (1999), the human system is categorized by rising complexity levels starting from the most basic level of 'existence' up to the most complex system level of 'psychological needs'.

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[26] Also referred to as Anthroposphere.
[27] Sentient aspects of psychological needs, as well as ethical references of conscious systems are not taken into consideration in this study. The system hierarchies are only discussed up to the level of 'coexistence'.

- *'Existence: The system must be compatible with and able to exist in the normal environmental state. The information, energy, and material inputs needed to sustain the system must be available.'*

→ Is the system compatible with and able to exist in its environment?

Basic factors of existence can be indicated through birth rates, health status, energy supply, food and water supply. In the context of urbanism the most basic support structures like buildings, health care facilities and water supply built the first level of existence.

- *'Effectiveness: The system should, on balance over the long term, be effective (not necessarily efficient) in its efforts to secure required scarce resources (information, matter, energy) and to exert influence on its environment when necessary.'*

→ Is it effective and efficient in its processes and operations?

The indicators for the effectiveness of a human system are employment, income structure, transport, waste management and the local economy. Hence effectiveness components of the urban system include roads and transport, waste management, commercial, industrial and service building typologies.

- *'Freedom of action: The system must have the ability to cope in various ways with the challenges posed by environmental variety.'*

→ Does it have the freedom and ability to respond to environmental variety?

Coping with the variety of individuals and a divers ethnic composition, the social structure of the urban system can be supported through facilities for education, worship, culture and heritage.

- *'Security: The system must be able to protect itself from the detrimental effects of environmental variability, i.e., variable, fluctuating, and unpredictable conditions outside the normal environmental state.'*

→ Is it secure, safe, and stable despite a variable and unpredictable environment?

The safety of the built environment can be indicated through social problems, welfare and social security, crime. The urban system contributes through the urban structure and the enabling of facilities for security facilities.

- *'Adaptability: The system should be able to learn, adapt, and self-organize to generate more appropriate responses to the challenges posed by environmental change.'*

→ Can it adapt to new challenges from its changing environment?

Soft factors to enhance adaptability can be evaluated via levels of creativity, non-governmental organisations, entrepreneurs, training and research facilities and involving professions. For the urban structure it mainly constitutes the function of building typologies.

- *'Coexistence: The system must be able to modify its behaviour to respond appropriately to the behaviour of the other systems in its environment.'*

→ Does the total system have compatibility with its partner systems?

Here Bossel identifies socio-cultural factors of communication and community involvement that have the ability to enhance a higher state of co-existence in the city. Those relate to areas of communication/information infrastructures in a city or also at spacers that enable communal gatherings.

The last level of the human system complexity relates to sentient and conscious systems.

- *'Psychological needs: These constitute an additional indicator for sentient beings.'*

→ Is it compatible with the psychological needs, which are relevant to this system?

This level is concerned mainly with the individual development and hence exceeds the capacity of the scale of architecture and urban environment to contribute directly. There might be of course indirect effects, but the analysis of those and their relevance to architecture and urbanism is left here for other experts to be tackled.

Furthermore, rather than just thinking of enabling basic needs for existence, security, effectively and freedom of action within the built environment, architects and urban designers can add to a higher adaptability and coexistence for individual development and the community through their concepts and designs. Other soft factors to improve the human environment to a more viable and adaptable system can be achieved through community administration, citizen participation, non-governmental organisations, etc. But those are mainly concerning the Government system and therewith exceed the perspective of this study of the support system/ built environment.

In conclusion the human environment and the system components thereof are summarized in the following table as a set of indicators, which the urban and architectural system directly and indirectly relate to through the establishment of compensation structure (e.g. food and energy supply via infrastructure, built structures for existence, employment and cultural activities, design for community activities, etc):

	Anthroposphere	
Levels of complexities:	0410	Indicators of system viability
Human system	Indicators	
existence	birth rates	Is the system compatible with and able to exist in its environment?
	health	
	sun	
	energy	
	food	
effectiveness	employment	Does it contribute to the efficient and effective operation of the total system?
	income	
	transport	
	waste management	
	local economy	
freedom of action	education	Does it have the freedom and ability to respond to environmental variety?
	religion	
	cultural heritage	
security	crime	Does it contribute to the security, safety and stability of the total system?
	waste management	
	city structure	
adaptability	creativity	Can it adapt to new challenges from its changing environment?
	non-governmental organisations	
	entrepreneurs	
	training	
	evolving professions	
coexist	communication	Is it compatible with and does it contribute to the interacting subsystems?
	community involvement	

Table 3→ System Elements Human Environment: Anthroposphere

This work identifies the built environment and its infrastructures as a support structure between the human and natural environment.
Other support structures, such as the government system, economic system and social system, can be also considered also as support systems but are not within the scope of this work.

0420 Natural Environment

In this chapter, natural resources applicable to the built environment are summarized. They provide the basis of the analyses of the natural system driven components of the ecology of the built environment in Chapter 0500. Later on, in the forming of the overall interrelation matrix, the further identified elements built the foundation of all necessary streams and flows into the urban system.
The composition of the natural system or eco-sphere as discussed here composes 'natural' energy and resources from the biosphere, atmosphere, hydrosphere, lithosphere and pedosphere of the planet.
Systematically, the source of renewable energies, solar power, delivers primary energy sources like water power, wind power, solar irradiation and biomass. 'Non-renewables' like hydrocarbons are not discussed here in this work as resource for the built environment. In contrast, the resource flows offered in the final conceptualization in Chapter 0600 maps solutions that differ from any hydrocarbon driven urbanisation with the goal of self-renewable properties of cities and architectures of the future.
Hence the considered natural elements that influence the built environment as driving force and resource provider are ordered here in sun (solar power), wind/air (atmosphere), water (hydrosphere), biotic matter (biosphere) and a-biotic matter (lithosphere and pedosphere).
The laws of thermodynamics interconnect all sub-spheres driven by the dynamic atmosphere. 'The first law of thermodynamics states the equivalence of heat and work and reaffirms the principle of conservation of energy. The second law states that heat does not of itself pass from a cooler to a hotter body. Another, equivalent, formulation of the second law is that the entropy (a thermodynamic quantity representing the unavailability of a system's thermal energy for conversion into mechanical work, often interpreted as the degree of disorder or randomness in the system.) of a closed system can only increase.' (Oxford Dictionaries, 2013)

Sun

Sun and its energy powers are a source of all renewable energies on planet earth, with primary energies like water power, wind power, solar irradiation and biomass.
Those primary energies are converted via natural energy conversion to products, which are useable for the technological transformation of energies into useable forms of energies that can then again power the human beings compensation 'skin' of the built environment.
Solar irradiation has the ability to heat the surfaced of the earth and atmosphere. That heat can be retrieved through heat pumps and used as heat-energy. Also solar collectors transfer irradiation into heat-energy, whereas solar cells and photovoltaic convert the photo irradiation into electricity.

(Behling et.al., 1996)

Water

After the sun as the source of all energy and biomass through photosynthesis, water constitutes the most important element of life on the planet. Apart from the raw product, waterpower can systematically be transformed into electricity through hydroelectric power plants.

Air/Wind

Wind power is subject to the atmosphere's movement (wind) and can be converted via wind-generators into electricity. Wave movements powered by wind can be directed also into electricity.

Biotic Matter

Biotic matter (from the Grreek word 'bios' meaning life) is all subject to biomass production via photosynthesis. Biomass can further be used to power heat- and power plants and to be converted into fuel.

Abiotic matter

Abiotic matter is not subject to converting energies into the built system but it supplies most of the construction and building materials used in the built environment defying gravity. On the other hand, abiotic matter is in most of the cases of contemporary fabrication methods converted into construction materials and goods within using energy of the conversion methods of above. The aspect of converting matter into materials through the input of non-renewable energies is in this work considered as active technologies. Current rapid urbanisation booms contribute into an energy consumption pattern for construction that is the highest in the world next to transport and industry.
As will be shown in the traditional case study analysis in Chapter 0500, the contrast to contemporary building methods and building typologies and their inherent energy consumption patterns, explain the shift need in rethinking the conversion methods of abiotic matter into construction materials and other goods.

The above-mentioned technological conversation processes are depict a general indication.
State of the art solutions for the transformation process of renewable energies will be discussed in more detail in Chapter →0433.

0430 Built Environment

> *The idea that we live in something called 'the environment' . . .is utterly preposterous. . . 'Environment' means that which surrounds or encircles us; it means a world separate from ourselves, outside us. . . . The real state of things, of course, is far more complex and intimate and interesting than that. The world that environs us, that is around us, is also within us. We are made of it; we eat, drink, and breathe it . . . No settled family has ever called its home place an 'environment' . . . The real names of the environment are the names of rivers and river valleys; creeks, ridges, and mountains; towns and cities; lakes, woodlands, lanes, roads, creatures, and people. (Berry W., 1992, p. 34)*

General tendencies of overcoming environmental problems are caused by the production and operation of the built environment, which are mainly being discussed by specialists and experts in certain fields (e.g. emissions experts) and solved through specific technologies (e.g. Co2 storage). The connections between the sourcing of raw materials, converting those into products that accumulate to built environment, and the operation and recycling thereof, are in most cases not seen as a whole cradle to cradle story that works on energy in- and outputs. Here the architect and urban planner needs to be introduced to an ecological understanding of the built environment as organism or system that relies on the natural environment and its inherent flows of energy, resources and information, in conjunction with the purpose of urbanism defined by the needs of the anthroposhere(→0410). Through a systems view we realize that objects themselves are networks of relationships, embedded in larger networks. Transferred to the urban system, flows and elements of physical, spatial and structures for flow throughputs are concerned.
Therefore this study asks for the processes and components that shape the in- and outputs to the system of the built environment comprising the urban →0431, the architectural scale →0432 and technologies of energy and resource transformation →0433. The overall order here is a mere stencil or pattern of elements of the built environment and it is not tackling the qualitative contents of those elements or system components in terms of shape and/or form. All resources required and converted into the system of architecture and urbanism are part of, and derives directly from the natural environment →0420. The other determining border of the system of the built environment is the anthropological environment that at the end defines the needs of a city or architecture through various levels of socio-culture, governance and economy →0410.

This approach seems similar to the science of urban metabolism as described below, but this study concentrates more on inherent strategies (according to living system principles →0330) of the connections of elements and flows to its surrounding environments and not on a engineered quantities approach of resource flows.

Urban metabolism theories

Urban metabolism may be defined as ‘the sum total of the technical and socio-economic processes that occur in cities, resulting in growth, production of energy, and elimination of waste’. (Kennedy et al., 2007)

In practice, the study of an urban metabolism involves the quantification of the inputs, outputs and storage of energy, water, nutrients, materials and wastes for an urban region. ‘Cities transform raw materials, fuel, and water into the built environment, human biomass and waste’ (Decker et al., 2000).

Since the inauguration of the term ‘urban metabolism’ by Wolman in 1965 the study had the practical reason to quantify air pollution and other wastes produced in US cities, which shall be later discussed in an extended format under the subject to ‘The limits to growth’ and the resulting forming of the UNEP (→0120). The diagram below shows quantitative throughputs based on calculations by chemical engineers, ecologists and civil engineers of Brussels in the early 1970s.

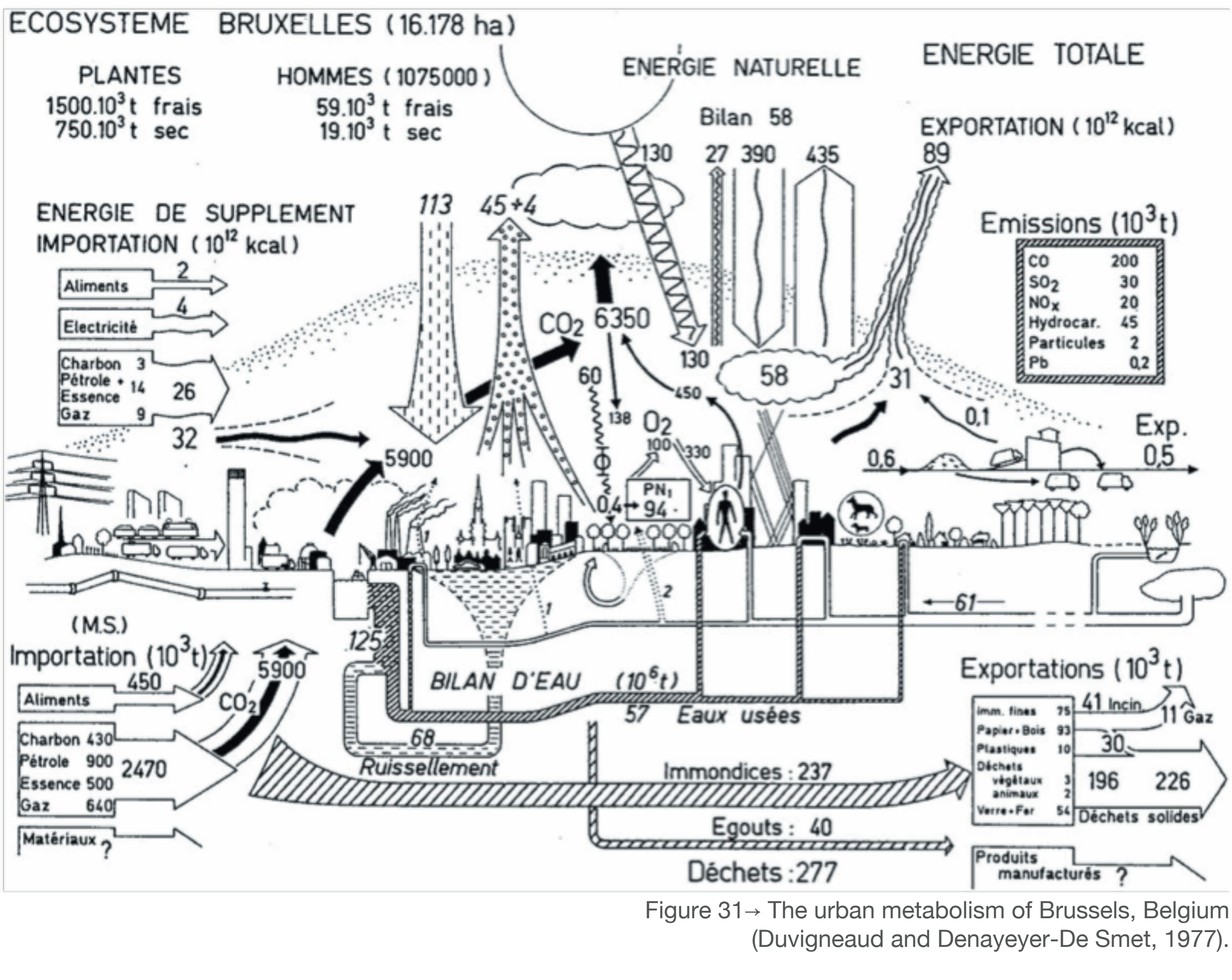
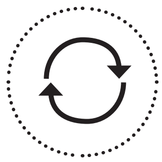
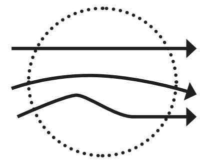


Figure 31→ The urban metabolism of Brussels, Belgium (Duvigneaud and Denayeyer-De Smet, 1977).

Those accounting principles appear yet again in most of the architectural rating systems (e.g. LEED) that base their philosophy on the reduction of energy and water demand and the resulting emissions. World future council co-founder and architect Herbert Girardet defines the key components of a sustainable city as ‘circular metabolism’, which assures the most efficient possible use of resources.(Girardet, 1992)

In contrast to current linear metabolism, where coal, oil and nuclear power form the main inputs next to food and goods that produce outputs like organic wastes (landfill, sea, dumping), emissions (CO_2, NO_2, GHG), and inorganic wastes (landfill), he argues that a circular metabolism minimises pollution and wastes in landfills through organic waste and material recycling.

Compared to the system strategies as retrieved in →0330, Girardet’s model compares to the second highest out of six strategy groups concerning effectiveness through the ‘respond’ (recycle, reuse) strategy of metabolic systems: Cycles  and flows .

Obviously the orders of the built environment for this study have to be structured so as to leave space to the other four hierarchies of strategies. Thus the available natural system comprising of energy and resources are dealt with as flows into the built environment. The throughputs of flows are localised at the different urban and architectural elements of an urban system and are ordered according to scale. The technological transformation of energy and resources required to be fed into the system is also structured according to natural system components. Here, the transformation processes of active and passive approaches are considered.

0431 Built Environment: Urban

The urban environment can be regarded as an ecosystem in which humans live and interact with biotic and abiotic elements. This system is structured here into infrastructural flows of energies and matter based on the input of the natural system into the urban system: sun, wind/air, water, gravity, biomass and materials. Due to envisaged cycling strategies, the input elements are directly related to output elements such as waste water, solid waste etc. according to natural system components. The flows are captured through urban spatial elements that can be identifies as: open space, green space, transit space, built up space and topography/land use. The latter is used in a qualitative definitional model of investigation, which basically is a soft-function of spatial elements.

The defined nodes of interconnections on the urban and architectural level shall retain proximity and yet also be flexible for interpretation, since the following case studies to be compared under those levels have different timely connotations.
Another argument for the proposed order of urban system elements is the required flexibility for different approaches in city-making: the contemporary top-down approach of urban planning and the traditional growing self-organisation approach from bottom-up. Also, settlement functions and the resulting urban structure have changed over the centuries according to prevalent socio-economic streams. Hence the biotic and non-biotic elements inscribe topography as a connection-node as well as the main land use function. Green space also leaves purpose driven interpretations from recreation to arable useable land. Open space is not defined as public space since the definition of 'the public' might refer to a basic democratic principle of shared space like in many 'Western' societies, but might not be applicable to constitutions of certain other countries (like a monarchy, in the case of Oman).

	eco-sphere		built environment compensation
CORRELATIONS	0420		0431
	nature	planner	urban
flow	sun	flow	orientation/shade
			lighting
	wind		cooling
			ventilation
	water		potable water
			waste water
			storm water
	gravity		waste solid
			goods
			transport
			communication
matter	biotic	elements	topography
			green space
			transit space
	abiotic		open spaces
			built up spaces

Table 4 → System Elements Built Environment: 0431 Urban

0432 Built Environment: Architecture

Architecture compensates the functions of human needs by providing available energies and resources from the natural environment. To structure elements of buildings as considerable nodes that can be interlinked with other nodes of other systems (natural, urban, human), the table below is structured into flows (according to natural system flows of energies and resources) and elements, which consider physical building parts. The form and performance of architecture as parts of the built environment underlie concepts of planning and design strategies, and these will be further analysed in different case studies (→0500) and discussed in Chapter →0600.

	eco-sphere			built environment compensation
CORRELATIONS	0420			0432
	nature		architect	architecture
flow	sun	flow	flow	orientation/shade
				lighting
	wind			cooling
				ventilation
	water			potable water
				waste water
				storm water
	gravity			waste solid
				goods
				access/circulation
				communication
matter	biotic	elements	skin	facade
				insulation
			skeleton	walls
	abiotic			roofs
				slabs
				foundation
			space	zoning
			components	openings
				windows
				doors
			material	construction materials

Table 5 → System Elements Built Environment: 0432 Architecture

0433 Built Environment: Technologies

Energy and resources that feed into the urban system can be converted from following naturally occurring primary energy forces: Solar, Air/Wind, Water and Biomass. Those are then naturally converted into sun-irradiation, heat energy (solar), wave movement, atmospherically movement (wind), rain, convection, melting (water) and biomass-production (biomass).
So far establishes technologies transform those naturally according energies and resources via active and passive energy approaches[28] into consumer-friendly units like electricity and heat. The table below state the various options of transformation technologies:

	eco-sphere		compensation
CORRELATIONS	0420		0433
	nature	transformer	technology
flow	sun	energy	solarcollectors, heatpumps
			solarcells, PV
	wind		wind generators
			wave-powerplants
	water		water-powerplants
	gravity		energy storage
matter	biotic	matter	(non-) and fossil fuels
			heat-and powerplants
			material
	abiotic		material

Table 6→ System Elements Built Environment: 0433 Technologies

Due to the goal of this study to reach environmentally adaptable design strategies for the built environment, the technological transformation into fossil fuels is not a considered an option anymore for the supply of energy to the built environment. Other possibilities of renewable energy and materials transformation processes are listed in the table below.

[28] With help of energy = active technologies
Without support of transformation energy = passive technologies

Natural Environment→ energy and resources	Transformer Processes Material→	Transformer Processes of natural resources into Energy→
Sun		Solar Thermal Collectors, Thermal Solar Pond (saltwater), Thermal Concentrated (CSP) Concentrated Solar Power (parabolic, linear, dish, tower) Photovoltaics (PV), Photoelectrochemical Cell (PEC), PV Thin Film dye-sensitised (DSSC), PV 3-D Cells, PV infrared and UV, Thermophotovoltaic (TPV), Concentrated PV, Luminescent Solar Concentrator (LSC), Thermoelectric, Solar Chimney, Solar Chemical.
Wind		Horizontal/Vertical Axis Wind Turbine, Concentrated Wind, Windbelt.
Water		Hydroelectricity (Damm, Run-Off, Pico-Hydro) Vortex Power, Hydrokinetic (tidal, current, wave), Osmotic Power, Ocean Thermal Energy Conversion (OTEC), Geothermal.
Matter → biotic	Plants, microbes, animal by-products,	Biogas, Ethanol, Biofuel (Solalgal fuel, biodiesel, syngas, vegetable oil, hydrocarbon plants, biogasoline, solids), waste to energy, microbial fuel cells (MFC).
Matter → abiotic	Metals, minerals	
	Others…	Kinetic energy harvesting, piezoelectric micro harvesting, energy storage, hybrid engine, thermal storage.

Table 7→ Renewable energy and materials transformation processes

0440 System orders overview

The results of this Chapter appear in a summary of all the system inherent flows and elements of the natural, human and built environment, which shape the analysis matrix for the following analyses of the case study, which centres on Oman on the Arabian Peninsula. The spectrum spans from the available eco-sphere resources that form the input for the technological transformation into usable energy and resource for architecture and urbanism. Flows are depicted in the form of sun, wind, water and gravity that influence urban and architectural infrastructures, whereas matter (biotic and abiotic) is a source for physical built structures. The purpose of the three different compensation areas, namely technology, urban and architecture, derive from the functions, which are fundamental to the anthropogenic environment. The ways in which planners, architects, engineers and other stakeholders involved in the making of built conditions of settlements can interlink all the given different environmental components into a comprehensive ecological whole are given in the strategies.

Table 8 shows the flows and elements of the ecosphere as input into the built environment and the human environment related to system strategies. The ecosphere is already arranged to very close to each level of system layers, whereas the ecosphere and built environment are delineated in a direct flow order from left to right. The same occurs with the astrosphere in conjunction with the system strategies from left to right. The missing links of all the axes of nature, human and urbanism as interfacial support system shall further be established in Chapter →0600.

The less detailed diagram of
Figure 32 depicts the main nodes of the order structure, but leaves the observer with the question of how these points actually correlate specifically.

The linkages for those nodes or system elements will be examined in the following chapter through case studies of two settlements in Oman. System inherent strategies as underlying concepts for connections of the urban and architectural system shall expose the inherent complexity of the level of system of each demonstration.

Table 8→ System orders of Built, Human and Natural Environment

COR-RELATIONS	eco-sphere		built environment compensation		built environment compensation		built environment compensation			correlation strategies		anthroposphere
	0420		0433		0431		0432			0330		0410
	nature	transformer	technology	planner	urban	architect	architecture	details	complexities	concepts	human	indicators
flow	sun	energy	solarcollectors, heatpumps,	flows>	orientation/shade	flows>	orientation/shade		secure	reduce	existence	birth rates
			solarcells, PV	sun	lighting	sun	lighting					health
	wind		wind generators	wind	cooling	wind	cooling					energy
			wave-powerplants		ventilation		ventilation					food
	water		water-powerplants	water	potable water	water	potable water		respond	reuse	effectiveness	employment
					waste water		waste water			recycle		income
					storm water		storm water			conserve		transport
	gravity		energy storage		waste solid		waste solid			mimic		waste management
				matter	goods	matter	goods			flexibility		local economy
					transport		access/circulation			resilience		
					communication		communication		protect	preserve	freedom of action	education
										efficiency		religion
matter	biotic		(non-) and fossil fuels	elements>	topography	elements>	skin	facade		cultivate		cultural heritage
			heat-and powerplants		green space			insulation		self-sufficient	security	crime
		matter	material		transit space		skeleton	walls				waste management
	abiotic	matter	material		open spaces			roofs				city structure
					built up spaces			slabs	adapt	integrate	adaptability	creativity
								foundation		adapt		non-gov organ.
							space	zoning		self-regulation		entrepreneurs
							components	opening		co-existence		training
								windows				evolving professions
								doors	change	manipulate	coexist	communication
							material	materials		self-renewing		community involvement
										co-evolution		

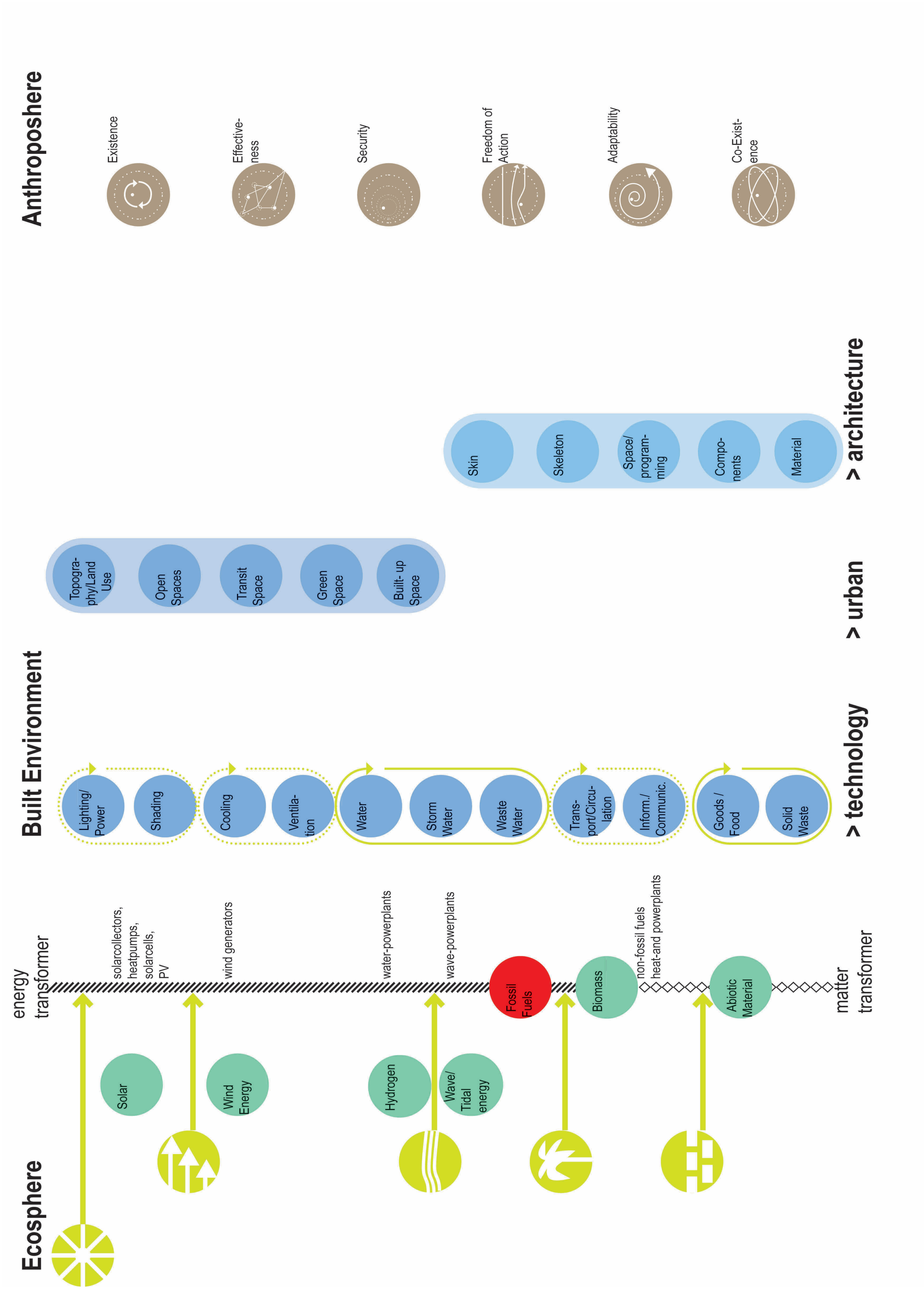


Figure 32→ System Orders Result

0500 Case Studies

Synopsis

The author has chosen the Sultanate of Oman as representative for settlement development in the desert region of the Arabian Peninsula. In this chapter case studies of self-sufficient oasis settlement systems before the introduction of hydrocarbon revenue (Ibra, Al Mansafah (MFA) →0510) and the fossil energy export induced peri-urban settlements (Muscat Capital Area, Al Khoud (MCA) →0520) are analysed (in 0510 and 0520) according to the system orders (see →0400) and compared regarding their inherent system strategies (see →0330) in Chapter 0530.

A brief introduction to the historical, political and cultural development of the Sultanate of Oman is delineated in the following:

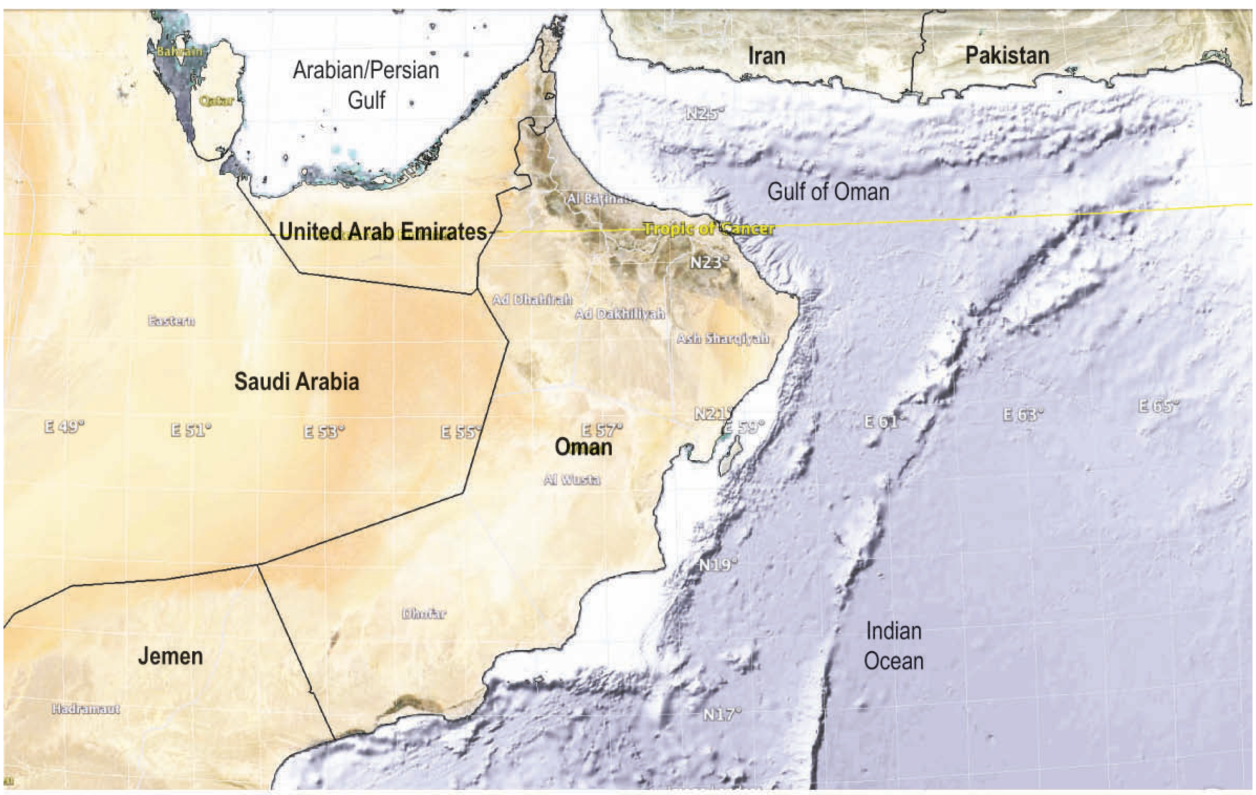


Figure 33→ Map of south-eastern Arabian Peninsula

Development of Oman

The Sultanate of Oman represents the main area of the south-eastern Arabian Peninsula and was first mentioned in cuneiform writings as »Magan, the Land of Copper«. Its development refers back to a history of over 5000 years where it started out due to the fortunate geo-political location as a key figure for trade in the Middle East, Asia, and Africa. Seafaring, fishing, cattle breeding, and agriculture formed the basis of this civilization's existence until oil and gas fields were discovered in the mid-1960s.

The geography of the country divides it into three partitions, the mountainous North and also heart of the country, the desert area south of this, and the maritime south. The Hajar Mountains in the North are reputedly the source of the abundance of water that is available in this region and have rendered possible the development of a complex irrigation system and the resulting evolution of the oasis-based culture. Countless fortresses and settlements bear witness to a history of settlement activity going back as far as the third millennium B.C. s a result of its strategically favourable location, power interests also extended to the inner Omani regions in the first millennium B.C. It was not until the end of the 19th century that Omani territories in parts of eastern Africa had to be relinquished in the face of the growing influence of the colonial powers. In the 1970s, Oman was caught up in the oil boom and, within a brief period, cultural, social and economic changes took place and a modern development began (Gangler, 2008).

Before the Sultanate was founded and united as one country, the regional differences and the clan like structures were apparent in all living and building environments.

Now Oman is divided into five regions (*mintaqah*) and four governorates (*muhafazah*). The fourth governorate, Al Buraymi, was created in October 2006 from parts of the Ad Dhahirah region. The regions are further subdivided into 61 districts (*wilayat*). Each region has one or more regional centres with a grand total of twelve. The 2010 census counted a total population of 2,694,094, with an overall Omani population of 1,951,100 people, whereas in 2003 there were 1,781,558 with a growth rate of 9.5% over seven years. Consequently, a growing housing unit demand of 26.7% can be seen between 2003 and 2010. The massive changes introduced in the seventies have had a major impact on the morphology of cities, the ecology of the place, and the social coherence of communities.

A new constitution

The rapid changes, through a new constitution, for the nationalization of the Sultanate include a newly introduced leadership organisation. Population growth demands a centrally governed organisation of land distribution, which resulted in the Royal Decree 81/84 (1984). Through this degree, every Omani older than 23 years is entitled once in a lifetime to a piece of land that is being

distributed by the Ministry of Housing of the Sultanate Oman. At this point the strategy of developing urban areas experienced a massive change from the previous decentralized organisations of land distribution in the regions.
With a flag, a constitution “The white book”, and an anthem, the new united country was born. Modernization was glimpsed through the perspective of the West, which promises comfort as a vital factor to lift all citizens into convenient modernity. The Muscat capital area represents the new hub to cover all those promises. With a total population of 734,697 the capital area attracts a massive part of the Omanis (General Census of Population, Housing and Establishments project, 2010).

Traditional settlement form

If we look closer at Omani society, we can still feel the diversity amongst the people and their communities, even in the peri-urban Muscat Capital Area. Their family names relate closely to the region and the village their family community is originally from. Cultural relics, like dress, music, poems, stories, handicraft, and different decorative patterns are just some outstanding indices of the underlying deep connectivity to those roots.
A comparison of case studies of the recently introduced post-oil discovery consequences to the capital area (→0520) and the settlement of a traditional oasis village (→0510) with all its ecological, social, and morphological consequences will reveal the massive changes that happened on those levels from 1970 onwards.

The Renaissance

Settlements all around the Hajar Mountains in Oman that date back up to 8000 years ago to the Stone Age e.g. the settlement of Ibri. The characteristics of those settlements before the changes introduced by Sultan Quaboos with the so-called ‘Renaissance’ from 1970 onwards, were of decentralized, self-sufficient units that connected to the natural living environment as a guarantor of survival. The community or tribal system was self-regulated and cultural differences become apparent from region to region.
The sudden loss of previous life-environment and political-economical environment let the indigenous society almost forget about the valuable ways of not only surviving, but also of establishing high-cultures through a very close connectivity with their environment. Abruptly, things that were carefully thought of were eliminated out of the common consciousness and replaced by imported goods as barter between depleting fossil fuel powered energy sources such as oil and gas and imported products. Additionally, the social level experienced immense changes. Land entitlement distribution no longer worked through well-established village communities but through a national lottery. Previous groupings were now distorted all over the place and mixed into a new order.

Before the development program for most of the regions was introduced in 1972, the now national land was tribal land. Land ownership and land use were based on common law and systems were adapted to the environment. The Bedouin nomads believed that all land belongs to camels and goats; they would browse the trees and bushes in the *wadis* and shift camp at comparatively frequent intervals. The destruction of natural resources would have entailed an immediate threat; hence living through sustainable pastoral practices was the only way of survival.

Changes

To win the hearts of a manifold nomadic and tribal population and to mark the ascendance of modern development the ruler introduced free material aid and government services (Martha Mundy, 2000).

Within a few years direct interventions caused by the new constitution resulted in all the important functions of the community being taken over by the government. Previous systems were ignored and this collapsed the social and ecological structure of the tribes. New legal and moral concepts undermined the practices that had maintained the natural resources and guaranteed the livelihood of the tribes in their defined territories. The de facto extension of the government led to the weakening of the politico-legal and socio-economic independence of the tribes. In 1974, the Omani government nationalized all open 'uncultivated' land. Formal legal conditions were created which enabled the state to implement development measures in the lands of the nomads without obtaining the tribe's agreement and without facing claims for compensation from the nomads. Omani Land Law regulates buildings, industrial areas and farmland.

The reduction of self-regulatory responsibilities, based on the 'all land is government land' forces, relinquished the traditional knowledge to organise societies and utilise built environment. The loss of this knowledge and the environmentally (natural and human) inappropriate and largely abortive development contributed largely to the ecological degradation in the area.

The Settlements of the Case studies

The challenges for the future of urbanism in post-carbon times for the Middle East depends fundamentally on the synergies analyzed of past and present times under consideration of ecologically viable strategies (Refer to →0110 for further challenges of the region).

The following case studies have been chosen to represent the traditional pre-hydro-carbon economy settlements and those of the contemporary city in Oman. The past oasis settlement of Al Mansafah MFA was a previous cluster of decentralized oasis towns, situated at an economically important trading hub of Oman in the past. Present urbanisation is mainly occurring in the Muscat Capital Area; hence also one case study of the suburb Al Khoud MCA is presented as a contemporary example of urbanisation patterns. According to the analysis patterns developed in →0400 both sites are analyzed in their urban and architectural dimensions in relation to human and natural ecological linkages.

Both case studies have also been chosen due to their characteristics of being outside the land-locked area of the Omani mountains (where most of the traditional oasis settlements in Oman actually occur) in order to serve as representative examples of the bio-climatic circumstances that are mainly prevalent on the Arabian Peninsula. Ergo, both case studies have a low elevation, slight inclination in topography of a plain area next to a *wadi* system, and similar bio-climatic circumstances.

Another criteria to choose Al Mansafah as traditional case study is that it represents a relatively dense urban clustered fabric and courtyard typologies of buildings. Courtyard architectures feature in many arid hot desert areas as a solution to the bioclimatic and socio-cultural circumstances. The traditional Arabic Islamic dwelling manifests itself as a spatial entity planned around courtyards. However it appears untenable in central Omani settlements such as Nizwa, Bahla, and Manah (Bandyopadhyay, 2011). Therefore the author has chosen Ibra’s Al Mansafah as a case study in order to find a higher identification value for other hot-arid cities and architectures in desert regions.

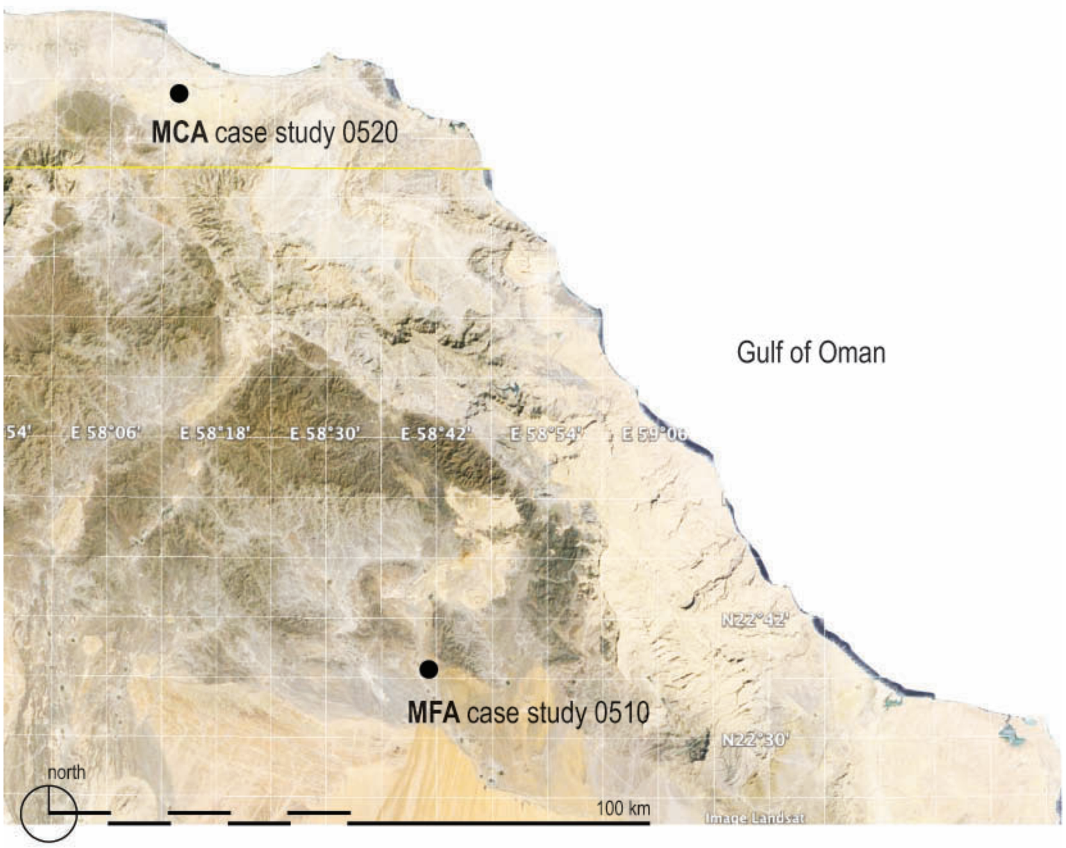


Figure 34→ Case study locations in Oman

0510 Past oasis settlements: The case of Al Mansafah MFA

Figure 35→ Al Mansafah in May 2011

> *Traditional social systems recognized some aspects of this interdependence and enforced community control over agricultural practices and traditional rights relating to water, forests, and land. This enforcement of the 'common interest' did not necessarily impede growth and expansion though it may have limited the acceptance and diffusion of technical innovations. (UN, 1987)*

Case Study pre–oil revenue: Traditional Settlements in the case of one oasis town Al Mansafah in Ibra, Ash Sharqiyah Region

Looking back on the Arabian Peninsula around sixty years ago, prior to the economical wealth of oil and gas explorations that simultaneously brought power supply through active technologies introduced by industrialized nations, we find structures that have been built and maintained in socio-cultural compounds in the same shape and form over hundreds of years without any heavy amendments. Therefore those settlements are a valuable indicator for human activities in the harsh and resources scarce environment of a desert through using passive technologies[29]. Due to the lack of water (annual rainfall ranges between 40 and 100mm) as the prevalent climatic condition of the Sultanate of Oman, traditional settlements can be found mainly at or around sources of water. Given those climatic conditions, agriculture in Oman relies on man-made irrigation.
Traditional farming systems have therefore been developed in geological or topographic settings where water was accessible or easily reachable (Luedeling and Buerkert, 2008).

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[29] here defined as non electricity consuming technologies

In most of the cases built environments have been integrated into the farmland. The following analysis thus concentrates on settlements or oasis towns where the natural environment and the man-made infrastructure of agriculture and built environments are interlinked in a living system, which evolved via feed-back loops of amendments over time. Hakim (2007) elucidates that ‘these features of [the] living systems help explain how the local built environment developed in the traditional Islamic city as residents interacted with one another’ and the surrounding system of a hot arid desert environment. However the author does not consider socio-morphological changes in this case ever since the new constitution of the country in 1970, which resulted in a massive decay of those decentralized settlements and resulted in urbanisation along the main industrial areas of Sohar and Muscat (→0520).

Site and Region

The Ash Sharqiyah Region forms the Northeast border of Oman at the Arabian Sea in the east, borders the internal side of the Al Hajar Mountains from the north, and fringes the Wahiba Sand dunes from the south. The region consists of 11 wilayats (districts) with Ibra being one of them. It is located in the rich natural environment of springs, caves, and *falaj* (historical irrigation system) systems within an arid hot desert environment. Agriculture and livestock, as well as traditional crafts, still function as income sources within this region. As the second regional centre of the region, Ibra is a district whose economy is based on agriculture and also some crafts and traditional industries. The closest harbour is based at Sur on the southern-eastern coast of Muscat. The region’s history dates back to pre-Islamic times. It played a historical role not only as a ship-building hub, but also as a trading and navigation centre of the Indian Ocean Rim, China, and East Africa.

Ibra comprises the junction of two large riverbeds: Wadi[30] Ibra from the North and Wadi Wuryad/Garbi from the west. The geography of the irrigation systems shape two settlement areas: one in the upper area of the *wadi* stream and the other in the lower areas. Each has been occupied by different families or tribes: Upper Ibra with the Al Maskari tribe and in lower Ibra, where the following case study of Al Mansafah is located, the Al Harihi family resided (Diener, 2003). Those clan organisations maintain and structure the distribution of land and ‘public[31]’ buildings like the mosque, *sabla*, and *hammam* within their tribal boundaries. All those organisations are structured around water and the community, which results in polycentric settlement structures. Over the last forty years those traditional settlements have been gradually decaying as a result of the socio-economical shift of the society in Oman. In the meantime, the old quarters of upper and lower Ibra,

[30] Wadis are waterbeds that carry water in the rainy season (December, January) and are otherwise dry riverbeds
[31] ‘public’ here does not necessarily imply that those areas are accessible to everyone, but may only be permitted for members of the clan and/or befriended tribes, nor that those areas are permissible for women.

including their agricultural land-use, have been left for the benefit of ‘modern’ housing across the *wadi* beds on the east side and is now inhabited by approximately 25,000 citizens.

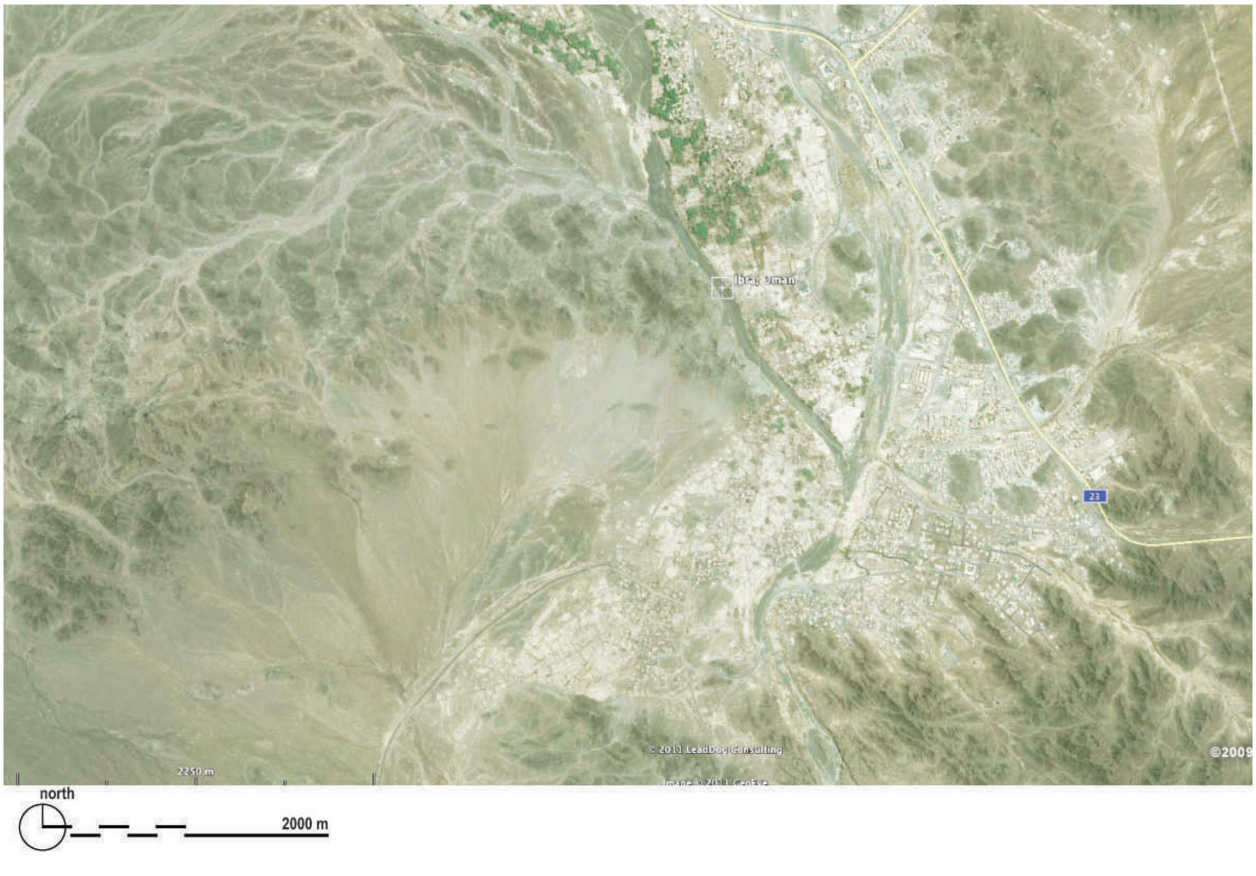

Figure 36→ Satellite Image of Ibra in 2012 (retrieved from Google Earth, 2013)

Methodology of the case study

Al Mansafah is part of the research on ‘Traditional Building Knowledge in Oman’ and was conducted in 2011 by the author and students of the 5th semester of the faculty of Urban Planning and Architecture at the German University of Technology in Oman. The research was structured to the following components:

- The oral history of old building masters in the region focusing on building materials, technologies and regulations.
- Case studies of selected traditional buildings in different regions of Oman.
- An archive of historical documents related to the case studies.
- Analyses of traditional planning and building regulations and the discussion of implementation into the 21st century thereof. (Refer to→ Appendix)

All those findings form the foundation for the analysis of the case study’s interconnectivity of the built environments to the human and natural environment. According to the system orders, as presented in →0400, system elements are described for the specific case study in:

→0511 Natural environment, →0512 Urban environment, →0513 Architecture, →0514 Technologies, →0515 Human environment.

Moreover the system connectivity strategies will be examined in comparison to the second case study of MCA (→0520) in →0530.

0511 Natural Environment

The development of Al Mansafah shows clearly the importance of water as main driver of an oasis town. Once the water supply can't be fulfilled due to environmental or economical changes, the livelihood of the community consequently decays accordingly.

Figure 37 and Figure 38 indicate the decrease of water supply in Al Mansafah between 2003 and 2005, which resulted in the decay of the surrounding farmland as well as in the migration of its inhabitants to a new town.

Figure 37→ Satellite Image of Al Mansafah in 2002 (retrieved from Google Earth, 2013)

Figure 38→ Satellite Image of Al Mansafah in 2012 (retrieved from Google Earth, 2013)

Traces of inhabitation of the natural environment in Ibra, which made life possible and sustainable in most arid regions of the world, go back to the Sassanids before 100 BC. They are assumed to have first built the *aflaj*[32] in this region that made possible the process of agriculture the base for the livelihood of oases settlements. Thus prevalent resources are:

Solar resource: There are two seasons, the hot dry summer during the months of May to October and the cool winter months from November to April. During the summer months the weather in the coastal area is hot, with temperatures up to 48°C, and humid, with relative humidity between 85% and 90%. With an average high temperature of 35.1 °C Ibra/ Al Mansafah gets around 10 hours per day on average. (Al Jabri, 2012)

Biotic Matter: In wadi Al Batha, agriculture is concentrated around Ibra, Ad Dariz, Al Ghabbi and Al Wafi. The area under crops is estimated to be 1500 ha in 26 oases irrigated mainly by the *aflaj* system. Due to the suitable soils in the region agriculture had good potential (Ministry of Agriculture Oman (2008).

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[32] sing. Flaj, intricate networks of irrigation systems

Abiotic matter: On the southern edge of the Hajar Mountains, which stretches from the tip of the Arabian peninsula to the north to south over 600km, limestone compiles the main abiotic resource available with eroded sandy plains. The dry riverbeds of the *wadis* also carry limestone pebbles. Construction materials are comprised mainly of natural stone, loam, and artificial pozzolan *sarouj* as binding agent for mortars and plasters.

Water resources: All agricultural land in the Sultanate has depended traditionally on *falaj* water for irrigation at a rate of 50-60% of the total available water, with an average discharge of 15-60 litres/sec. The greater region of Ibra comprises two *wadis*: one from the north 'Wadi Ibra' and one from the West 'Wadi Wurayd' (Gaube, 2012).
Shari'a (or Islamic Law) is the basic law of the Sultanate. According to the basic principles of Islamic law, water carries rights comparable to land, especially if developed and used for irrigation. Priorities: drinking water, where water is free for all for that purpose, while the owner has exclusive rights for other means like irrigation (Wilkinson, 1977).
Apart from the man-made irrigation systems, groundwater cumulates in the water tables of the *wadi* channels. It is also found as a non-renewable source, deep in the limestone.

Prevailing winds follow the regional network of the *wadi* systems connecting to the coastline. Therefore the main wind direction in the case of Al Mansafah is south and has an average velocity of 3m/s above ground level (Al Jabri, 2012).
As identified in →0110 one of the main challenges of hot arid desert developments is potable water due to limited resources. Low rainfall and high temperatures benefit evaporation and low recharge of aquifers.

0512 Built Environment: Urban

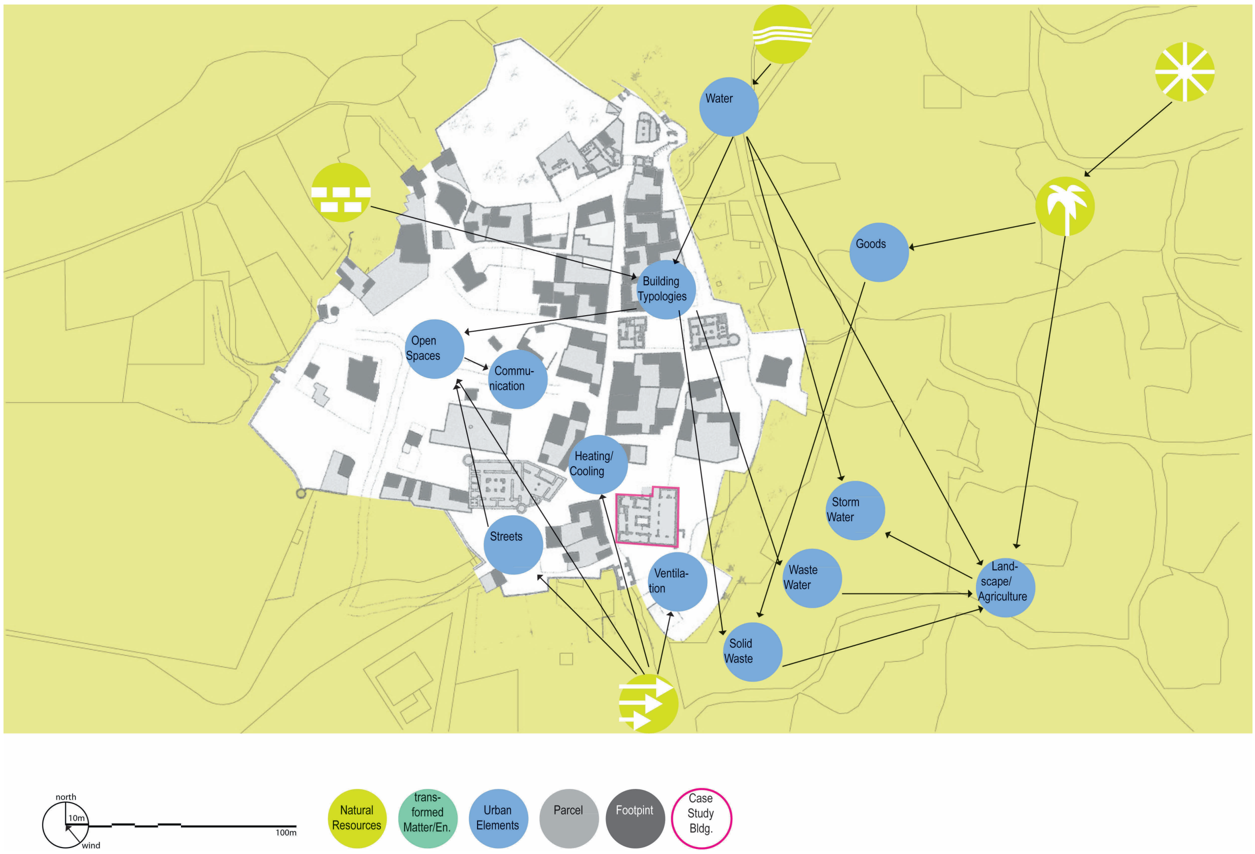


Figure 39→ MFA site plan

The settlement of Mansafah is located next to the al Quanatir in the north lower Ibra. The *wadis* are divided into lower and upper Ibra, which are each secured by fortification. To protect the rich mansion buildings in Al Mansafah from intruders, it was surrounded by a stone wall in the midst of a prosperously growing palm tree grove. It is one of the older centres of the cluster of several oases in Ibra, dating back to the construction Bayt[33] al-Buma in 1711 A.D. Unique mansions in Oman are preserved here that are characterised by excellent workmanship and embellished with rich decorations. Scholarly assumptions have led to the conclusion that the buildings were built by Omani merchants from Zanzibar and East Africa.

In the north was the Masjid al Hisab with a *sabla*; Byat as Sudur was nearby containing the seat of the govenor. There are even sources stating that Mansafah incorporated a library. Although the mansions are freestanding and not arranged in an urban cluster like in al Quanatir, the alignment creates an open space in the middle of the village that was used as a horse plaza for the merchant families to gather during their summer holidays from Zanzibar.

A sense of common law created a mutual responsibility for the common space through the inhabitants, which made it possible to have communal agricultural belt around the village that was

[33] Arabic for House.

irrigated by a flaj system connected to the surrounding Hajar Mountains. Before the description of the buildings follows, it needs to be noted that little has been done in documenting those jewels of Omani architecture. So far Al Mansafah lacks proper historical building documentation, analysis, and reconstruction.

Since the introduction of new technologies to construct, power, and maintain the built environment due to the revenue of oil over forty years ago, there have been massive changes to the traditional settlements and livelihood systems of oasis settlements. The following description and analysis will be mainly driven on sources acquired through oral history and case study mapping with Omani students in 2011 through the research on 'Traditional Building Knowledge in Oman' and on other literature source namely: Fred Scholz (1999), Damlujii (1993), Gaube (2008) and Korn (2008). The allocation of research results in maps reflect the status quo to date of the survey, considering the fact that most of the case study's area of arable farmland and built environment has almost entirely decayed. Hence the author will extend this case study with findings through a comparison with results of other traditional settlements in the region.

The typical oasis settlement layout differs from the patterns of coastal Islamic towns where an entire city is marked with one perimeter wall. Most of the oasis settlements, even the bigger ones in Rustaq or Nizwa, are compiled of smaller nuclei settlements. Several settlements are clustered over the whole oasis. Usually they are divided into upper (*alaya*) and lower (*sufala*) oasis settlements, according to the topography and contours of the land. Each section has its own centre and mosque. The social distribution of the population is organized along tribal lines (Buerkert et. al, 2010).

In the case of oasis Ibra, it comprises of three initial family tribes: In upper Ibra live the Al Masakira tribe, and in lower Ibra (Al Qanatir and Al Mansafah) reside the Al Hirth tribe. Other oasis settlements of the interior of Oman have not been protected by massive fortification buildings (Bahla, Rustaq (Sassanid), Nakhal 815 CE, Nizwa 845 CE, Mirani (portugese 1590 CE), Jalali (portuguese 1687 CE), but through walls, watch-out towers, and also though the shape of the oasis buildings per se.

The space between the settlements could be used for regional markets and buffer zones between the tribes. This spatial distribution of living space according to kinship can be found in other Arab-Islamic settlements in the Middle East and North Africa. The general procession from public to semi-public, then to semi-private and private can be observed.

Interestingly, this spatial layering system of fractals of spaces, from private to public, from cool to hot, from dark to light, can be seen as being responsive to the climatic situation of the hot arid desert environment, also to the social tribal systems of the community, and moreover it adheres also to belief systems.

Concepts of traditional urban form

Traditional Arab-Islamic principles of the built environment differ from the contemporary 'Western' approach of a quantitative understanding. Here, land management creates smaller fragments of space through subtractive concepts of subdivisions. The constitution of such societies and their inherent planning decisions follows a top down process based on democratic processes.
Whereas on the Arabian Peninsula, before the restructuring of monarchies took place shortly after the exploration of hydrocarbon resources the powers were not carried collectively as a nation but as a conglomeration of sheikh-doms. Here the tribal community governs the built environment through an incremental and organic additive formation of parts. Hisham Mortada (2003) identifies those parts in four layers of depending hierarchies: the first layer describes a group of quarters inherited by one tribe. Each quarter is then ruled by tribal subdivisions. Between those, spaces are allocated to serve the quarters functioning as the second layer. The third inherent layer is the private properties, which are again interconnected through spaces serving those private properties, which comprises the fourth layer. So in total there are four ascending principles of spaces from private (house), semi-private (quarter), semi-public (market) and public (Friday Mosque), those together form the cellular units that create the overall structure and cluster-like tissue of the city.
Those traditional towns resemble an organic entity of natural and social-cultural values. Aspects of the traditional urban fabric are shaped by processes of inclusion; of different social groups within the social sphere. Closely knit accumulative spaces and minimal distances between spaces add to the distinguished traditional morphology. The irrigation system connects the landscaped agricultural production land with the man made fractal clustering of the compact urban fabric. Master craftsmen and masons were able to create a self-sustainable and ethical built environment with the norms of *hurmah*[34].
Planning processes were determined by consultation with neighbours and the interest of the community. Each individual unit contributed and thereby enhances the vitality and unity of the urban form. The compared case study of the Muscat Governorate in the following chapter reveals how the comprehensive (ecological and social) approach of traditional settlement is discontinued through the introduction of rigid constraints to the previous cumulative and additive making of nestled systems, into a system of separation of society based on economic and functional criteria.

[34] *hurmah* is a pre-Islamic notion of the sacred and protected time. Social relations become manifest, spatially and architecturally. *Hurmah* evolves from the symbolic socio-cultural value to the territorial values of architectonic form. (Salama, 2002, p.127)

Elements of the urban system:

Topography/Land Use

With the public spaces of *souq* (market), and the bigger convention space being allocated to the north of Al Mansafah and South of Al Qanatir, the remaining uses of land can be described as semi-public whence entering one of the five gates leading into the walled oasis settlement. Apart from the private properties (which are analyzed in depth in the following chapter) the remaining uses are dedicated to worship (see mosques at the north gate and at the road junction in the centre), communal areas in the centre of the cluster, and for transport of the thoroughfares. The agricultural land use lays outside the walled settlement as a belt surrounding the nucleus of the built cluster.

Open Spaces

The concept of *hara* (the central quarter) (Buerkert, 2010) as the centre space and heart of the community materialises at the crossing of the main thoroughfare, adjoined by a Friday mosque and *sabla* as a meeting lounge for the neighbourhood. Usually, open or public spaces use ground that is devoid of rich soil. The organic growth of built up spaces within the city walls from outside to in consequently left open spaces and paths in the hierarchy of planning as a leftover space. The same dynamic growth principles apply to the traditional Arab Islamic residences. Here architecture is conceived not as detached objects, but as shaped according to the needs of the users. The design and layout of the building matches the location in which it was developed and with it the ability to integrate into the existing urban fabric. The building itself is an interior focused space, very different from the idea of extroverted 'Western' architecture.

Transit Space

The major throughway is a pathway connecting the north and the southwest gate. Apart from its daily use for pedestrians, goats and camels, it was traditionally used for horse races. The layout follows the contour line of the topography, parallel to the *wadi* and the irrigation channel. Another pathway can be traced to the west along this, also the main space where the celebration for the end of Ramadan (Eid) was located. The main throughways led directly to the gates of the fortified settlements in the north, south, and west. Gatehouses and towers comprised the openings in the city wall.

Green Space

The topography of the area and especially the slope for the irrigation system shaped the landscape of the oasis. Agriculture has been arranged on man made terraces perfectly aligned to the man-made irrigation channels according to their distribution value. To the east side most of the arable terraced land towards the *wadi* declined slowly into the *wadi* bed. All oasis settlements depend mainly on a green belt of agriculture where Omani oasis farmers grow a large array of different crops and fruits with most of the area dedicated to groves of date palms (phoenix dactylifera L.). In the given case study of MFA the built up area comprises around one fifth of the farmed land surrounding it as a green belt. The agriculture is fed by an over ground irrigation system that nourishes the terraces starting at the lower edges of the dense cluster of the settlement on the south and east borders of the slope. All the terraces fields receive their main shading through six to eight meter high date palms sown with a variety of crops and fruit at their bottom. The fields are fertilized via human and animal manure. All elements of a palm-tree are used as resources for products, from construction to weaving and fuel.

Built-up Space

In most of the oasis towns of Oman the building typologies range from one or two story clusters of cells (size and complexity depend on available natural resources) for residential uses, hypostyle buildings for mosques (mainly congregational mosques) and gallery typologies for *souqs* (commercial) buildings.

In the case of Al Mansafah, some of the remaining ruins indicate the existence of two to three story courtyard buildings for residential uses, which are otherwise only found in coastal settlements of Oman, and are the most prominent example of climate adaptive architecture within the Arab Islamic building typologies. The transgression of spatial hierarchies for socio-cultural conditions is met perfectly in the courtyard typology of building, as will be described later. Apart from the public buildings like the mosque at the crossing of the two main thoroughfares, and the previously adjacent *sabla* (meeting space for men), all the buildings were residential typologies organized in fairly compact clusters.

Flows through the urban system:

Lighting/Shading

Compact clusters of buildings were oriented west to east.

Cooling/Ventilation

Ventilation aisles (which also functioned as thoroughfares) oriented into the prevailing wind direction from the sea to the south. The palm tree groves surrounded the settlement as a buffer zone and thereby enhanced the microclimate.

Water

Water and irrigation in the scarce environment of the desert is the source of any life. Hence technologies have been established over thousands of years in such climate zones to bring the water to the desired location. In the case of Oman the water sources of mainly fossil basins are located within the Hajar Mountains or other aquifers underneath the sandy desert surface. The Ministry of Information in Oman distinguishes three types of *aflaj* systems used in Oman over the last 1500 years out of the total 4,300 *Al aflaj* systems:

'• Falaj Daoodiya*: These type of* falaj *are like long channels dug under the ground. Their width varies from 0.5 m to 1 m in height, from 0.5 to 2 m in depth, or 50 m on ground level. The length of some flaj reaches up to 12 km. These long* falaj *represent 45% of the total number of Al-Flaj in the Sultanate and their water is available for most of the year.*
• Falaj Ghiliya*: Similar to canals, these* falaj *carry water from the running surface or semi-surface water, with depths not exceeding 3 to 4 m. The quantity of water in these flaj increases during the rainy seasons. In most cases these types of* falaj *dry when rainfall stops for a longer period of time. Their length varies from 500 to 2,000 m. Their width depends on the type of valley and its discharge. This type of* falaj *represents 50% of the total number of* aflaj *in the Sultanate.*
• Falaj Aynia*: These type of canals take their water directly from the spring, its discharge varies from 0.5 litres/second (l/s) to 30l/s.Their height ranges from 5 to 50 cm, and the length of these* aflaj *varies from 200 m to 1,000 m. The number of these* aflaj *in the Sultanate is limited to about 5% of the total number of* aflaj*.' (Al Jabri, 2012)*

In our example of Al Mansafah the main water source derives from a *Falaj Daoodiya* system from a spring in the *wadi* located to the north west of the settlement in *Wadi Ibra*. Figure 40 gives a general overview of the schematic sequence of water flows via *aflaj* into the settlements and the farmland. In MFA the entry of the irrigation channels into the oasis settlement is marked by wash structures for women and men until it reaches a huge basin in front of the mosque. Before the washing areas potable water is diverted for drinking purposes. After leaving the public open basin, the *falaj* is then diverted into separate singular channels to reach the different farming terraces. The distribution of water into privately held fields has traditionally been calculated via astronomical calculations and sundials. To close the cycle of water use in oasis systems, the grey water of the households as well as the dried manure of humans and animals are then distributed onto the farmland as fertilizers. The irrigated water is then filtered through the soils and rocks of the farm terraces back to aquifers. Figure 40 gives a schematic section and plan of the water cycling through oasis settlement.

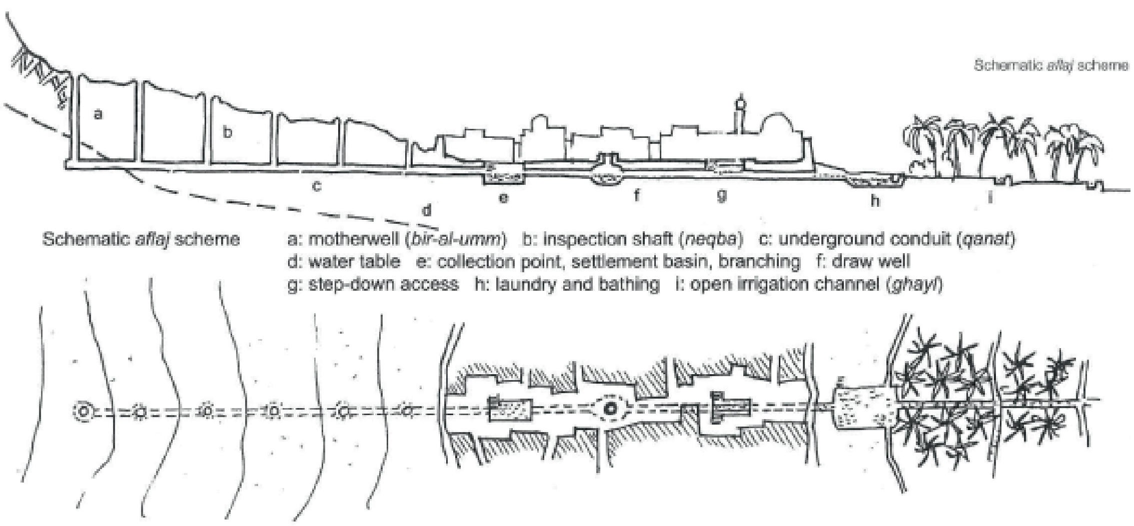


Figure 40→ Diagram of water cycle and according oasis layout (Ragette, 2006, p.69)

Waste water

Grey water resulting from human consumption is used for the irrigation of the surrounding agricultural fields. Black water is dried and used as fertiliser (see also Solid Waste).

Storm Water

The *wadi* system is a naturally eroded and shaped storm water system. Terraced fields along the *wadi* beds are designed and built to use the storm water (only once or twice a year) to distribute water in the fields and to let it be stored in man-made 'aquifers' along the natural *wadi* systems.

Transport/Circulation

The circulation system ensured that the network matched the character of the space and the social needs of the users. Hence, the main thoroughfares were traditionally integrated into souks, secondary corridors into residential neighbourhoods, and tertiary alleyways into the clusters of private homes.

In clear transcending hierarchies, the circulation system worked to connect and interrelate the various social and bio-climatic components of the urban fabric.

Roads were not planned, but treated as left over spaces between the buildings. Direct see through and also ventilation means were achieved through dog-legged thoroughfares. Whence, shaded in the early evening, women would also sit outside on the lane and thereby expand family life into the communal realm. Sharp bends allow lanes to function as contained courtyards, enhancing privacy and containing cool air.

Communication

The semi- public areas of the mosque and the *sabla* are the main communication hubs for the men. Women use informal coffee ceremonies inside their houses to meet with the other women of the oasis. Outside the walled hamlet, Ibra inhabitants meet at the souk or the convention space for celebrations.

Goods/Food

Food and livestock were produced directly inside the oasis, whereas other goods would be traded in the *souq* to the north of the oasis clusters Al Mansafah and Qanatir.

Solid Waste

Plant and animal organic waste would be composted and distributed to enrich the soils of the oasis lands. Human manure is cumulated inside the buildings through vertical discharge shafts. Once dried after one year, it was used as fertilizer for the agriculture.

0513 Built Environment: Architecture

"As far as architecture is concerned, it is the haven where man's spirit, soul and body find refuge and shelter ... "
(From an urban management manual by Ibn Abdun, an Andalusian judge 12th century CE)

Figure 41→ MFA south elevation (2011)

Figure 42→ MFA floor plans perspective (reconstruction, not to scale)

Figure 43→ MFA cross section perspective (reconstruction, not to scale)

The most common building typology of Al Mansafah comprises of two to three story courtyard buildings. Since the migration of its inhabitants, to new Ibra or Muscat, started over the last twenty years the condition of the buildings has suffered rapid dilapidations.

The courtyard house, as the most common used building typology in the Arab region (but also in similar climate zones from China to Morocco), provides an effective shelter in the harsh environment. Exterior openings can be minimized and thereby mitigate the effect of sun radiation, heat, and hot prevailing winds. Secure closed rooms and semiprivate outdoor spaces make sure to protect the Muslim family and their needs for different stages of privacy. Separated areas for male and female quarters, family areas, housekeeping, and formal functions are distributed in a radial manner around the courtyard.

Arranged in urban clusters the building's elevations to the public play a minor role. The major concentration is directed to the introverted core of Muslim private family life. In those urban settings buildings are not designed as freestanding volumes, but as a succession of organically grown clusters. The urban clusters, as well as the building per se, are designed with an exact understanding of the hierarchy of volumes, wind flows, sun impact, and temperature differences between night and day. Here the courtyard building typology fulfils the requirements of the harsh climatic environment, water scarcity, and a necessity for security to protect the sensitive life of humans, plants, and animals as a fractal of the overall urban form. The *bayt* (house) plays a vital role in the Omani society for the notion of home and fatherland. It represents refuge, shelter, and retreat (Bandyopadhyay, 2011). Moreover it protects the inhabitants from harsh climatic conditions and invaders, providing infrastructure for survival as the 'Cradle of the family'. The family unit in the traditional Islamic society vitally functions as the container of customs, traditions and a socio-cultural continuum.

The buildings in Mansafah, although appearing as proud entities, are not extroverted to the outside elevations. Building height and the amount and size of openings illustrate the distinct wealth. Some of the bigger mansions even have a circular watchtower attached to the main volume. Only one or two openings gave access to the buildings through wooden doors. Those had two opening sizes: one for camels including their package and a smaller one implemented into the overall gate for humans. The arrival room usually links to storage and the inviting courtyard that is proportionally small in the floor plan compared to the height. In summer only minimum sun is let in and the cross section benefits the air movement.
The one mansion used for this case study is located at the south gate of the village. It is one of the biggest remaining ruins in the village, previously used by merchants. Since no historic building documentation has been produced so far, the history of it still lies in darkness. Oral interviews revealed that in the 1970s it was used as one of the first hospitals in the country. From the existing building structure and the conducted interviews with local building masters, the following architectural elements and flows can be assumed:

Elements of the architectural system:

Skin

Approached from the south, the path sloped upwards to the gate of Mansafah, which disappears almost next to this majestic two-story stone and *juss* (fine lime cement mortar) mansion. The ground level has only a few openings; mostly long and narrow ones giving the impression of a fortified encounter, which is not easily accessible from the outside. On the north elevation, the mansion can be reached via two entrances; one for camels including baggage and servants, and the other to enter the main part of the building. Arcades stem from the first one, where a bigger courtyard for animals and outdoor work is on the left-hand side and the connection to u-shaped arcades, a small courtyard, and the living quarters is on the other side.
The second entrance is closer to the main village road, which was also used for horse races, and leads in to a reception area with a waiting bench. To the right, a staircase leading to the second floor continues the living quarter, which constitutes a family room with two equal sized rooms, and one smaller one in the southwest corner of the building.
The remaining plastered interior walls reveal a glimpse of the rich stuccoes and decorative work around the room in high niches. Around the courtyard massive arches open up the rooms around and provide them with necessary natural light; indirectly in summer and directly in winter.

Structure

Load-bearing masonry walls over three stories would have been erected through using the hard limestone and basalt from the region, in combination with a high strength lime mortar as an adhesive. Horizontal spans for slabs and roofs were constructed of wooden beams and loam infill floors and ceilings.

The wall construction of the upper floors was lighter than on the ground. Apart from reduced wall thicknesses (80-100cm in the ground floor and 40-60cm in the upper floors), walls had recesses for storage shelves and niches on top for distribution of the light that entered through the thin slits.

Space

The courtyard building is a perfect example of a synergetic relationship between the site's climate and the human needs and comfort. It represents a perfect connection link between the built, landscaped, natural, and human environments. The courtyard as the nucleus of the building represents a negative volume for the distribution of light, ventilation, and social interaction. Whereas other adjoining spaces of the compact building follow a spatial hierarchy of: Semi public (essentially male occupied areas), semi-private (restricted to the family and guests) and private (restricted to the family, particularly women). In terms of programming, the lower floors equip utility, storage, stable and kitchen, and also the guest space areas of the allies. In the upper floors, the more private spaces are aligned.

Components

Limestone plinths are directly built on to the existing rock topography and are finished off with sun-dried adobe bricks. Those loam bricks contain mainly the clay filled soils of the surrounding farmland, in conjunction with straw fibres to enable tensile forces. Slabs and roofs are constructed of quartered palm tree trunks and topped up with palm-frond woven mats filled in again with clayey earth (loam). Openings are fortified with either stone or palm-tree trunk lintels and filled with wooden shutters for door and window openings. More durable timber than palm tree wood is sourced from wild olive or juniper trees of the region.

Material

Locally available construction materials like natural stone, sundried adobe earth bricks, wood, lime plaster (*sarouj, juss*), and palm tree products were used. Due to the harsh climatic situation of the desert, loam as a product of the compositions of clay, silt and sand has various benefits, such as the ability to adhere and release humidity up to 90%. Additionally loam has insulation qualities of conserving the coolness of the night inside the spaces. Relative humidity, in combination with air movement through ventilation slits and the courtyard shaft, enables a wind chill effect, which adds to the cooling of the interior climate. In Ibra, most of the ground floor walls are 60-80cm wide in the upper floor, decreasing to 40cm. Such 40cm thick loam walls contain a U-Value of only 0.3 W/m2k, compared to concrete blocks that measure 3.3 W/m2k (Minke, 2000).

Since it is locally produced, not transported, and sundried (not burnt), the loam construction method as used in oasis settlements of Oman constitute zero-carbon construction materials. The production of the lime plaster and mortar locally called *juss* or *sarouj* was more energy intensive. In a week's procedure adobe disks and *wadi* limestones were burned on an equal amount of palm tree trunks, in order to achieve an artificial hydraulic pozzolan.

Flows through the architectural system:

Lighting

Daylight entered the introverted spaces mainly via the courtyard shaft and the thin slits of the lower openings. The upper floors had low windows protected by wooden shutters, which could be opened at night to let the cool air in. The building was in general designed to keep light and heat outside.

Shading

Due to the wall thickness, openings and their shutter enclosures sat inside the deep recesses and were therefore partly shaded. Otherwise the courtyard volume was self-shaded by the surrounding building volumes. Additionally, the bigger outside court on the east side of the building, had natural shading through the building volumes to the south and the west.

Cooling/Ventilation

Passive cooling was enabled though the thermal mass of the walls and the air movements. Ventilation slits above the door and window openings, in conjunction with the shaft of the courtyard (whose longer side was oriented towards the prevailing wind direction to the south), enabled air drafts throughout the building. Additionally the slightly wet plaster enabled the interior temperature to be reduced due to the wind-chill effect.

Water/ Waste Water

Drinking water was taken from the irrigation system of the *aflaj*. Additionally, our case study house had an interior well in the courtyard. A vertical latrine shaft divided liquid and solid particles of waste via a grid. The solid parts were dried for a minimum of one year and used as fertilizers on the fields again. The liquids directly perforated into the soil.

Storm Water

Over the year, Al Mansafah sees less then 100mm of rainfall. Waterspouts were used in the roof parapet construction. The walls situated at the changes in level were covered with horizontally laid stripes of natural stone slates that worked as water nozzles in order to protect the walls from water erosion.

Circulation

The access from the public zone encompassed a threshold framed by a two-winged door. The space elongated the threshold into a semi-public pre-space. The central core of the courtyard, utility spaces in the ground floor, and the family spaces in the upper floor link from this distribution zone. Vertical circulation was enabled through loam-constructed staircases that join the pre-space to the courtyard, which also served as a waiting area for visitors.

Communication

The centralized courtyard served as a hub of ventilation and lighting, and as a communication system inside the main building. The servants' quarters on the east side were also aligned to a common court.

Food/Goods/Solid Waste

The food/goods and waste organisation worked within a closed cycle. Organic food/goods came from the surrounding farmland and were discharged again as compost to those agricultural fields.

0514 Built Environment: Technologies

Active Technologies (non human or animal input/work required) are limited in oasis systems. Passive design strategies and processes helped to utilise prevalent bio-climatic resources.

Energy Transformer:

The active use of energy embodied in the biomass of locally or regionally available resources like palm-trees, acacia trees, or sir trees has been used to process food or construction materials (e.g. mortar).

Material transformer:

The transfer of locally available abiotic material for construction purposes is, apart from the plaster/mortar (Sarooj), based on the passive input of human labour and solar energy (e.g. Sun-dried adobe). Hence no active energy consuming transformation processes had to be used.

0515 Human Environment

No facts concerning the demographics, education, employment figures, etc. of traditional settlement strucures in Oman are available in present day research. However in his research on social patterns in the oasis of Al Manah, Bandyopadahyay (2011) describes the integration of religio-cultural and environmental factors as social time; five daily prayers are organized according to the movement of the sun; activities of different social groups and the allocation of social space revolved around those movement units. Routine flow, social interaction, and proactive economic duties each had their time and space. Communal properties included wells, *falaj*, bathing enclosures, mosques, *sabla*, and the transit spaces.

Existence [birth rates, food, water]:
Communal water wells are maintained and operated by tribal affiliations. Food and livestock were retrieved directly from the surrounding agricultural fields. The community acted as the support structure to all of its members.

Effectiveness [employment, income, transport, waste]:
Employment in those old settlement structures is directly linked to the work of the fields, family affairs, and trade. In the case of MFA, wealthier traders from east Africa have built their mansions with the support of human resources from the surrounding settlements and also foreign labour. Income is based on the trade of food products like dates, alfalfa, livestock, and handicraft services of textile weaving. Ibra was also a trading hub between the coastal port and the interior lands of Oman and additionally to the desert Wahiba sands in the South. Traditional oasis jobs for women included harvesting, procreating in the family, livestock care in house, and management of the social structure. Male duties were pollinating, herding, and other field work outside of the house.

Security [crime, waste, military expenditure]:
In the fortifications of walls and observation towers surrounded MFA, the community organized their defence system, firstly in their own settlement, and secondly through agreements with neighbouring settlements.

Freedom of Action [education, religion, cultural heritage]:
Five prayers a day would determine the activities during the day:
1. Prayer (men pray at mosque, women at home) 4 and 6 am: the males work in fields while the women prepare lunch and eat lunch2. Prayer 12 – 2pm: men meet in *sabla*, women work in fields or dwellings

3. Prayer 3.30-4 pm: men meet at *sabla* or work near dwelling, women work near dwelling and prepare for dinner
4.Prayer 6 – 7.30pm: dinner at home
5. Prayer 8.30-9.30pm: men meet in *sabla*, women put children to bed
(Bandyopadahyay, 2011)
'*Madrasah*' education (which concentrated mainly on the reading of the Koran) was either attached to the mosque or *sabla*.

Adaptability [innovation, research, creativity, NGO's]:
In the past, the traditional way of life meant that there were hardly any possibilities to evolve. Systems of settled communities existed over hundreds of years without any change. The economic shift that has been introduced in the 1970s is proof that the oasis system was limited in terms of adaptability for the individual and communal evolvement, and thus is no longer a model people can comply with in their day-to-day life.

Co-Existence [communication, community involvement]:
Communication and community involvement occurred gradually: first in the same family, then in the tribal community, and later between the fortified villages. Open fields where souks, auctions and celebrations took place were common trading and activity spaces.
Courtyard buildings as a typology have been part of the Arab world since the third millennium B.C.E. With the expansion of caliphates from the Mesopotamian region to North Africa and the Middle East, the courtyard became an essential typological element, adhering to bio-climatic and socio-cultural dimensions of an Arab-Islamic community.

0520 Present peri-urban sprawl: The case of Muscat Capital Area MCA

.Figure 44→ Al Khoud in MCA 2013

> *'Our cultural critics chart a fateful dialectical equation for the survival of national and local cultures in terms of a cultural need for roots as well as wings: to be deeply rooted in its local soil while capable of soaring in the global flight. This problematic paradox embodies what is perceived as a total cultural crisis in the Arab-Muslim world today. Within this cultural crisis, contemporary urban development and the built environment lie in an unprecedented maelstrom of accelerated urban development and transformation.' (Al Harthy, 2002)*

Case Study post–oil discovery: Muscat Capital Area, As Seeb, Al Khoud Phase 3

The Muscat Governorate comprises six districts (*wilayats*): Al Amrat, Bawshar, Muscat, Muttrah, Qurayyat, As Seeb, and Al Khuwair. 27.3% of the total of the Sultanate's population live in the Muscat capital area, of which only 55.2% are Omani. As the capital area, the governorate plays a central role for Oman in politics, administration, economics, and administration of the Sultanate through holding the seat of the government. The port, and the mainly governmental owned Petrol Development Oman PDO, is seen as the trading and economical hub for national and international affairs.

Industries include first and foremost crude oil production and refining, and natural and liquefied natural gas (LNG) production. A coastal line in the northeast fades into a mountainous waterfront in the Northwest. To the West the capital area ranges into a sand desert plain ground. The hinterland of *wadis* is dotted with occasional oases.

Climatic characteristics are typical of the hot, arid desert zone and environments along the north facing coastal plane of the Arabian Gulf, backed up with the Hajar Mountains to the south with long, hot and humid summers and warm winters.

The demand of new plots for the rising Omani population leaves the vast open western areas of the capital vulnerable to a functionalist sprawl that started in the 1980s. In 2009, due to the Royal Decree 81/84 (153077) new residential plots were to be provided in MCA with 89% for residential use. The gap between demand and delivery in the capital area has led the neighbouring Batinah coast to the northwest of Muscat to develop rapidly into the most populated governorate in the Sultanate with 619,937 Omani living there. (General Census of Population, housing and Establishments project, 2010)

This has resulted in a contemporary built environment with characteristics of sprawling urban fringes. Massive tracts of land are required for transit spaces (roads, highways, and infrastructure), landfill areas and large out-of-town shopping facilities, mono-use low-density residential areas, etc. If the outcome of a built environment is still engaged with natural and human context or is rather driven by market forces and processes disrespect a societal, collective, spatial and cultural production of urbanism, is explored in the following case of a typical recently planned and implemented settlement of Al Khoud in MCA.

Figure 45→ Satellite Image of As Seeb MCA in 2013(retrieved from Google Earth, 2013)

Methodology case study

The case study of Al Khoud is part of a university study called ‘My home is my castle’ (building analysis of contemporary residential villas in Oman) conducted in the summer 2011 by the author with students of the 4th semester of the faculty of Urban Planning and Architecture at the German University of Technology in Oman. The building survey of 30 villas resulted in: A siteplan (Scale 1/500), floorplans, sections and elevations (1/50), facade vertical details (1/20), roof details and material surveys for each structure. Thus the following detailed insight of a contemporary residential building in MCA can finally be compared to the previous case of MFA in the past, in terms of this study’s inherent goal of analyzing the interconnectivity of system components. (→0530)

0521 Natural Environment

Figure 46→ Satellite Image of Al Khoud/ As Seeb MCA in 2002 (retrieved from Google Earth, 2013)

Figure 47→ Satellite Image of Al Khoud/ As Seeb MCA in 2013 (retrieved from Google Earth, 2013)

The case study discussed is positioned on the southeast edge of the current agricultural plain of Al Batinah. The current rate of agriculture and consumption of food products in the Sultanate relies heavily on imports. The main importers of food are countries like India, China, Denmark, Pakistan, Iran, Philippines, Syria, and the GCC countries.

All agriculture in Oman is artificially irrigated due to the lack of precipitation, with an annual average of 100.3mm, and a humidity of 57.6%. Since 1970s the area under irrigation increased from about 28,000 ha to 72,588 ha in 2008 (Ministry of Agriculture Oman, 2008). Although 2.2 million ha are considered suitable for agriculture, groundwater appears to be insufficient for most areas. At present, groundwater depletion has taken place, especially in coastal areas, leading to seawater intrusion and deterioration of the water quality. By far the most important agricultural area in Oman is the Batinah region. This is a low-lying alluvial plain extending for about 240 km from Muscat to the borders with UAE, and extending about 30 km inland from the coast. It is located between the Hajar Mountain ranges and the Gulf of Oman. The Batinah region accounts for almost 60% of the agricultural production and has witnessed dynamic agricultural development in recent years. Crop production depends entirely on irrigation, with the main crops being dates, fruit crops, alfalfa, vegetables, and other forage crops. Over pumping of water in the last couple of decades has led to gradual seawater intrusion, causing irrigated water to include more saline. As a result, several agricultural lands of the coastal areas have become unsuitable for cultivation (Ministry of Agriculture Oman, 2008).

Agriculture production generates only 1% of the GDP of Oman, whereas most goods and foods ($23.37 billion (2012 est.) or over 30% of the GDP) are imported.

Other natural resources, in terms of biotic and abiotic materials, comprise: petroleum, copper, asbestos, marble, limestone, chromium, gypsum, and natural gas. In the construction industry, some limestone quarries are being exploited for natural stone claddings. Despite the vast amounts of limestone availability in the country, most of the cement is being imported from the neighbouring countries of UAE, India, or China. Steel is imported from China, Qatar and Turkey; Wood from China and Malaysia; Hardware from UAE, UK or Germany.

Another environmental factor is solar irradiation. Yearly sunshine hours of 3,493.3, with an average of a daily mean temperature of 28.61 °C, result in a daily solar radiation level ranging from 5,500-6,000 Wh/m2 a day in July, to 2,500-3,000 Wh/m2 a day in January. Hence Oman has the capacity for high solar energy densities (Norton Rose Fulbright, 2013), which can be used as an alternative energy resource.

Wind holds additional potential as a prevailing natural resource for the conversion of energy. Along the coastline of As Seeb, there is an average wind speed slightly over 5 m/s, and an estimated

2,463 hours of full load per year (Norton Rose Fulbright, 2013) reaches the case study area from the North-eastern direction from the 5km-distanced sea along the *wadi*.

The potential of natural resources like solar irradiation, wind, and abiotic matter are underused. The current practise focuses mainly on the import of necessary goods and products, whereas the agricultural production underlies the same challenges as discussed in the past setting of MFA. However, the unsustainable practises of fossil ground water withdrawals have led to heavy salinity of fertile ground, which is overcome by high (fossil) energy, which demands desalination processes. This has resulted in increasing energy consumption for the production of water, (importing) transport, and hence the pollution of air, potable ground water, and arable land.

0522 Built Environment: Urban

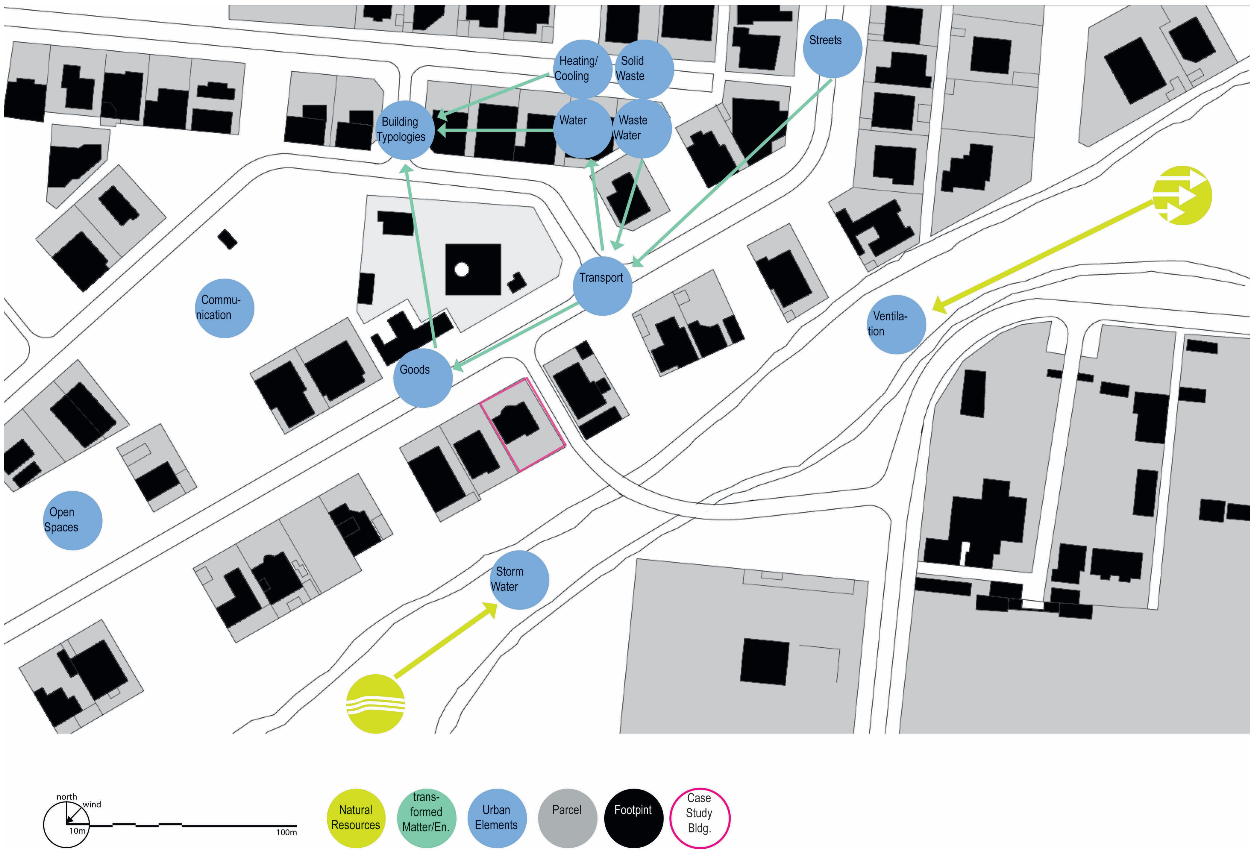


Figure 48→ MCA site plan

Elements of the urban system:

Topography and Land use

The case study of Al Khoud is part of the *wiliyat* (district) As Seeb within the Muscat capital area. Like all the other residential sprawls (e.g. Bousher, Ansab, Amrat, Mawaleh), it was planned as a regular grid of backed-up, double-row 20m by 30m plots. Communal spaces are not integrated and neither are other functions that would enhance a vibrant neighbourhood. The function of this layout is mainly residential with one religious and one commercial land use units. Communal out-door spaces are not considered.

Inhabitants are Omanis that have their family roots in the traditional organisation of clans and communities of the now mainly abandoned villages of the different regions in Oman. Now they live scattered throughout the sprawl, due to the distribution of land via lottery by the ministry of hous-ing. Individuals that are segregated from their previous social, economic, and cultural systems are outcome product of this method of dispersion of land.

The overall structural plan of Muscat, laid out by the Supreme Council of Town Planning of Oman, defines mainly mono-use zones of residential, industrial, commercial, governmental, and recrea-tional functions. Those functions exist within isolated areas next to each other and are only accessible through the transit road network. The separation of uses based on functional and economical criteria, defines no space of linkages for social and/or prevailing environmental systems. The natural force driven layout of the *wadi* as the natural system is disconnected to the layout of the built environment in flat topography.

Open space

Apart from the public road layout and the parking zones before the private plots there are no governmentally maintained public spaces in the case study area. Left over spaces are used for informal activities like football or waste dumping.

Transit space

The street layout of our case study also reveals that in most of the cases roads and access from two sides join residential plots. The street width and infrastructural corridor although low rise, low destiny residential areas, comprises around 20 to 30 meters.

Green space

No land is used for agriculture. Green spaces are subject to privately organized 'beautification'. The perimeters of the wadi are left over spaces that are not utilized or maintained. The wadi itself is merely storm water drainage for the low precipitation arising, especially during the winter time. Initially, as described in the case study of the Past, perimeters of wadi areas would be used for terraced farm lands in order to trap occasionally occurring water deposits on artificially sub-ground aquifers that could then be used throughout the year for irrigation.

Built-up space

Predominant building typologies comprise of freestanding blocks. Strict building regulations dictate (semi) detachments or clustering of built up areas. The same typologies are used for various uses. The only exception in our explored area is the line arrangement of the shops adjacent to the neighbourhood mosque.

Flows through the urban system:

According to the land-use policies, most of the infrastructural services are disconnected. Transport, power, and telecommunication flows determine the only grid like structures.

All other infrastructural needs; water supply, waste (grey and black) water, food/goods supply and the existing waste thereof, are transported via fossil powered transport in and out of the case study area.

Power

Throughout the summer of 2009 and 2010, Oman suffered severe power shortages, in part due to the rapid rise in demand. As with most countries in the region, the annual power demand in Oman is highly seasonal, with summer demand being more than double that of the winter due to the intensive use of air conditioning systems during the summer months. Al khoud's power supply is served by steam and gas turbine produced electricity from Al Ghubra (installed capacity of 498.8 MW (Al Ghubra Power & Desalination Company SAOC, 2013), some 20 km away.

Heating/Cooling

The cooling capacities of the buildings are met via decentralized cooling units. In most of the cases in buildings in Oman split unit air conditioning systems are used. Some denser residential developments may comprise of district cooling plants.

Ventilation

With the main wind direction from the northeast, the urban grid does not react to natural ventilation along the wadi. On the contrary, the street network and the resulting plot distribution have their 'back to the north-east direction on the east side of the case study area and open up spaces to the west, where the hot winds from the desert plains arrive.

Water

The Muscat zone is expected to reach 472,000 m3 per day by 2013. In the urbanized areas of current Oman, 85% of potable water is being produced through desalination (using both multi-stage flash evaporation and reverse osmosis technologies). The designated desalination plant for the case study area is Al-Ghubrah Power & Desalination Plant. It supplies the region of Muscat capital area with an output of 138 000 m3 per day by 2013 (Al Ghubra Power & Desalination Company SAOC, 2013). The plant runs on a multi-stage-flash distillation method that is highly energy consuming. This potable water in then distributed via water trucks into the neighbourhood.

Waste Water

On-plot installed septic tanks collect waste water for transport to a treatment facility in Al Ansab (20 km away).

Storm Water

The wadi area is utilized for the drainage of storm water. However roads do not have a drainage system that is linked to the storm water system, which causes massive flooding of roads in the rainy seasons.

Transport/Circulation

There is a low density and high land-consuming layer of MCA, as the peri-urban sprawl coincides with the importance of transport systems. All necessary supplies of water, goods, sewage and waste are managed through the network of roads.

Goods

Main food and goods are being imported into the neighbourhood via the road infrastructure. Bigger shopping malls some 20 kilometres away hold all necessary items. Concerning the slow implementation of private sector services and industries, it should be noted that most of the goods and foods are being imported to Oman. The main imports range from transport equipment (24 percent of total imports), electrical machinery and mechanical appliances and parts (18 percent); mineral products (14 percent), and base metals and articles thereof (13percent). The main import partners are the neighbouring United Arab Emirates (27 percent of total imports), Japan (13 percent), and the United States (6 percent) (Trading Economics, 2013).

Solid Waste

Solid waste is locally collected (without waste separation) and transported to landfills. Since no waste recycling programs are active yet, all kinds of waste including those that are hazardous, are being dumped into the soil at official, but also heavily at (around 350) uncontrolled 'dumping sites' mainly in the Northern adjacent Al Bathina region. Situated here are the main areas of fossil water irrigated agricultural land, and these might be negatively affected by the landfill pollution.

0523 Built Environment: Architecture

Figure 49→ MCA northwest elevation (2013)

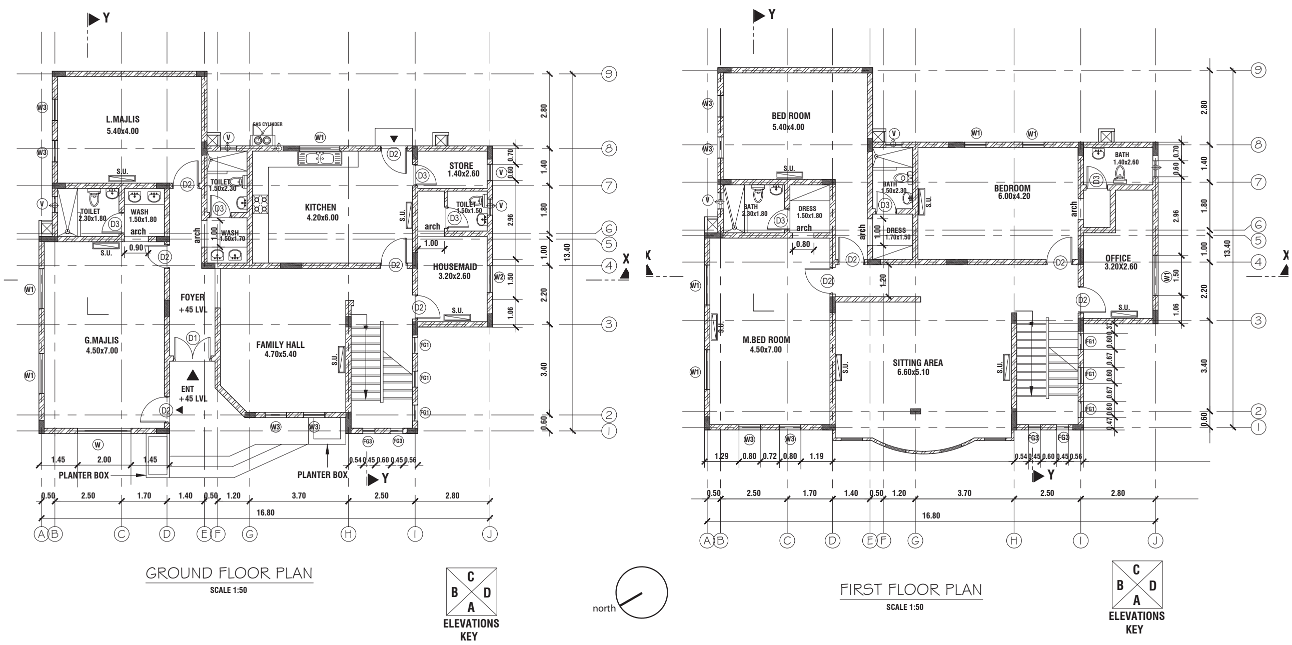


Figure 50→ MCA floor plans (not too scale)

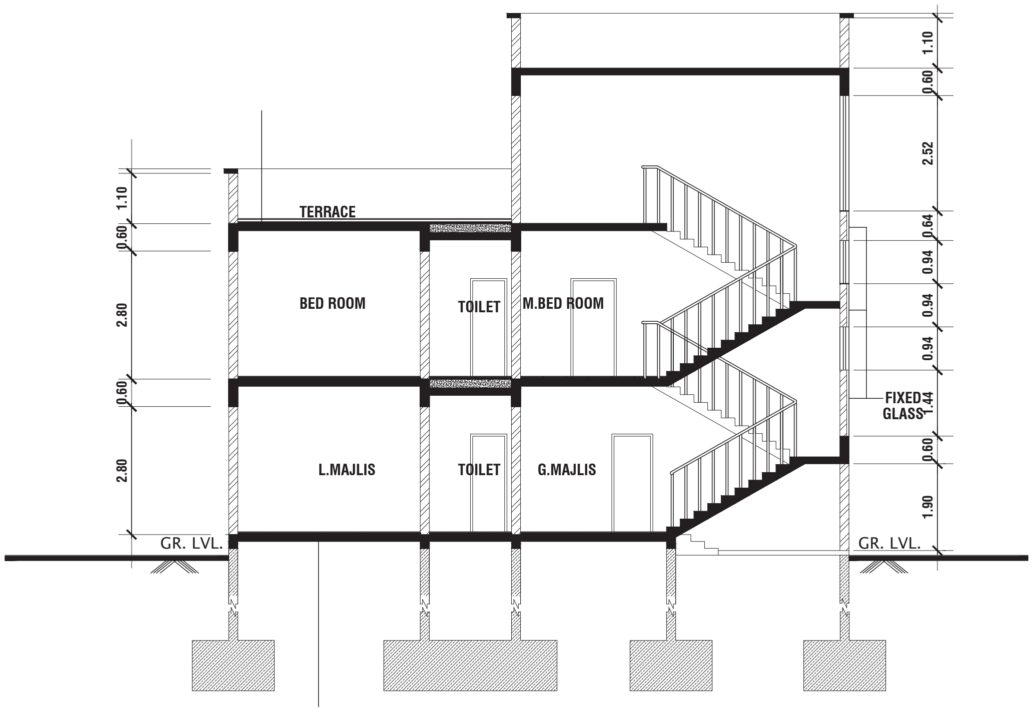


Figure 51→ MCA cross section (not to scale)

The case study of a residential building in Al Khoud is located on a distributed plot by the Ministry of Housing. This plot adheres to the royal decree 81/84 regulations to be of a minimum size of 600sqm and is entitled to an Omani above an age of 23 years. The design of the freestanding single family villa complies exactly with the Building Regulations for Muscat, issued on 9th Shawal 1412 H | 12th April 1992 by the Muscat Municipality via Local Order No. 23/92.
The built up area, in this example on the plot size of 782 meters square, makes up 34% of the land. Being set back from the street and at a distance to neighbouring buildings leaves the double story villa in the centre of the plot. It was built in 2009.

Elements of the architectural system:

Skin

The layout out of the plot as determined by the ministry of housing and the strict building regulations, dictates the orientation of the building volume to be its least favourable environmental affect. With the road and access to the west, this elevation contains the main entrance, the *majlis* and family area with large openings facing west[35]. Half of the building's surface is exposed to sun radiation and heat emission during the whole day, whereas the main wind direction from the north-east cannot reach the roof terrace since the three story high staircase block obstructs the wind hitting

[35] Oman lies on the 23rd latitude where west facing vertical elevations receive most of the solar irradiation (especially in summer).

the terrace. The non-insulated concrete plastered façade is painted with a light colour to reflect heat away.

Skeleton

The building structure is based on a concrete column slab construction with concrete hollow block infill (200mm), plastered without insulation material, and painted and decorated (e.g. grooves around the openings).

Space/Programming

The building stands in the plot in margins of two meters from the sides and six meters from the front.

The volume of the building is composed of an addition of four major zones. In the ground floor are the *majlis* (sitting room) area, followed by the family unit, the circulation part and the housekeeper area. In the upper floor the same array of usage patterns are transferred into bedrooms above the *majlis,* family area, circulation staircase leading to the ground floor, and onto the roof and the bathroom sitting on top of the servant quarters of the ground floor.

Components

The reinforced concrete frame construction is in-filled with concrete hollow blocks. Openings are closed with double-glazed windows/doors and plastic frames. Reinforced concrete slabs are only insulated on the roof. The masses consist of a double story box with a three-story high staircase core attached to it.

Material

In-situ produced concrete floors, walls and roofs are the main material used next to glass and ceramic for indoor tiling. Most of the products are imported from the UAE. Granite for external flooring is imported from India.

Flows through the architectural system:

Lighting/Power

The electricity supply is warranted by the power line infrastructure directly to the building.

Shading

No external shading devises are applied. Apart from the recessed entrance door the façade plains are arranged in a linear manner with no passive shading strategies (e.g. ‘brise soleil’). Hence openings are directly exposed to sunlight and heat irradiation.

Cooling

Split air condition units serve all interior spaces singularly. The compressors for the AC units are fixed without sun-protection on the roof.

Ventilation

Interior spaces are isolated artificial climate environments and are not connected to natural ventilation strategies (e.g. cross-ventilation).

Water/Waste Water

Like most residential buildings in the rising sprawl areas, the building is equipped with a water tank on the roof and a septic tank underground. Supply has to be served by fresh water trucks and sewage ('honeysucker') trucks that remove waste water (black and grey water).

Storm Water

Rainwater from the roof is directly drained into the ground.

Circulation/Communication

The family hall in the ground floor acts as the only radial distributer to the male and female areas of the building. Other rooms are accessed via 'dead-ended' corridors. The servants access is separate form the 'public' communication spaces and the common entrance of the building is on the backside (east elevation).

Goods/Solid Waste

No waste segregation or recycling systems are in place. All solid waste is collected in containers that are operated and maintained by the local government.

0524 Built Environment: Technologies

Unlike the oasis system the contemporary example of MCA depends heavily on active technologies, which enable urban and architectural components to be served with electricity and matter transformed products.

Energy Transformer:

Hydrocarbons are being transformed via gas and steam turbines in to electricity.

No other forms of energy are utilized.

Material Transformer

Major materials like steel and concrete are active-power transformed products.

The main materials in the contemporary construction industry used in Oman consist of reinforced concrete skeleton constructions with concrete hollow block infill, non-insulated. Although enough natural resources of limestone would be available, 90% of cement for construction is currently imported to Oman. All energy requires the transforming of matter into materials and products derived from fossil fuel powered energy transforming processes.

0525 Human Environment

In the following section some facts on the human environment in Oman are presented, based on Bossel's orientors of system hierarchies, as discussed in →0320. If not otherwise indicated, the quantitative facts are retrieved from the The World Factbook (2013).

Existence [birth rates, food, water]:
After the 1970s health expenditures are held up to 2.8% of GDP (2010) leading to an increased life expectancy of 74.22 years and a total fertility rate of 2.87 children born/woman (2011 est.). Also sanitation facility access has improved to 96.6%. Noteworthy is the fact that traditional tribal compounds have been made oblique through introducing a lottery system in 1984 to allocate land. Respectively families in monofunctional residential areas have not yet adapted to creating working local neighbourhoods, but rather live next door without coexisting community amenities like majlis or sablas.
Privatised companies regulate water supply, delivering potable water to each building's watertank (see also →0522). Here as well the local community that would previously decide over water rights are excluded from this initial binding element of settlements. As agriculture contributes only 1% to the GDP of the country, food and livestock are preliminary imported and distributed via regional (partly foreign owned) shopping malls. A direct link to local production and use of resources is disconnected also by foreign (predominately Asian) labour.
Mismanagement of stock storage, expiry of imported products and climate control has led to a substandard hygienic situation of food supply.

Effectiveness [employment, income, transport, waste]:
As a result of disconnected local and regional production of food and goods, the employment rate has risen to 15% by 2004. Employment opportunities are mainly generated at governmental sectors and majorly for administrative duties. Private industries are majorly serviced by guest workers. The very young population of male citizens is covered by recently rising employment options in the military or police. Additionally the Omani government has issued so called 'Omanisation' decree that aims to replace the 35% (of the entire population) strong expat working population by Omani nationals. The oil income provides the country so far a comfortable well-fare status but as warned by the International Monetary Fund (IMF) to fight overt state spending and continuous budget deficits by raising non fossil-power revenues (Gulf Business, 2014).
Infrastructural expenditure has provided the metropolitan areas with extensive road networks that inherently shape the low density, monofunctional peri-urban sprawl of contemporary urban planning. The topography responding trading pathways through mountainous terrain have been mod-

ernised by massive in carved, topography neglecting highways with an ongoing tendency of with another 78bio$(US) to be spent in the coming 5 years.
As described in →0522 waste management has not been controlled yet against environmental damage (e.g. groundwater pollution) and still remains non-separated and un-cycled even for hazardous debris.

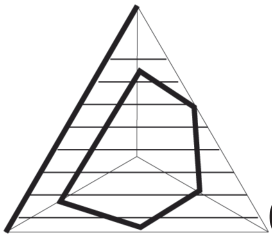
Security [crime, environment, military expenditure]:
Rising waste landfills and the resulting environmental damage has not yet reached a security issue for the low population respective to the land area. Although the reserves of drinking waters are gradually depleting or are subject to salination (especially in coastal regions where most of the population lives currently), which leads to further desalination (currently 85% of the total used) and again to further environmental risks. In the meantime 73% of total population (2010) with a growth rate of 2.3% (2010-15 est.) live exactly in those environmentally challenged coastal regions.
Crime protection delivered by police and military are subject to high expenditures: 11.4% of GDP (2005 est., which is almost three times as much as the education budget).

Freedom of Action [education, religion, cultural heritage]:
After the renaissance in the 1970s the literacy level has reached in 2013 86.9% of the total population. Also higher education facilities (mainly colleges and universities) have been introduced, but previous knowledge on agriculture and craft are subject of the past and hence are not transferred into societal and governmental recognised apprenticeships. Yet again leaving local industries and knowledge to be dominated by imported labour and expertise.
This is also reflected in the diverse mix of different religious backgrounds into the initially Ibadism (Ibadhi Muslim (official) 75%; Sunni Muslim, Shia Muslim and Hindu : 25%) coherent society.
However as trading region over centuries Oman has always been a melting pot of diverse cultures; thus various languages are spoken beyond the official Arabic: Swahili, Baluchi, Urdu, English and other Indian dialects

Adaptability [innovation, research, creativity, NGO’s]:
Since higher education services are just about to create a competitive market and the schooling system still has to provide the ways for critical thinking brains, the country is lacking output of research and innovation with a research budget of 0.1% of GDP (2009).
Besides some governmental universities an array of private university institutions are aspiring, although driven as for-profit business entities and hence disregarding the concept that ‘real’ universities have the obligation not just to teach but also to create new knowledge and innovation via research.

In recent years however the government (knowing of the importance of adaptability for the development of their nation) tries to combat this lack via installing support programmes (e.g. The Research Council and Innovation Park Muscat).

Co-Existence [communication, community involvement]:
As the Sultan of Oman (previously Muscat and Oman) was put into power in 1970 as monarch over at least 350 tribes (that all had their own decision making council of elders and a tribe leader/sheikh) the community of this newly created country had to first be established. Over communal discontent resulting in 'Arab Spring' demonstrations in 2011, a publicly elected council (*majlis al-shura*, a lower chamber of the legislative branch) subordinate to the monarch for legislative drafts, has been granted by the Sultan (chief of state and head of government).
Other communal activities revolve apart from privatised commercial environments (e.g. shopping malls) mainly around religious celebrations (Ramadan, Eid). Local community meeting grounds like the *majlis* and *sabla* are successively transferred to coffee shops and other commercial outlets (that are also frequent by females), which also leads the local commune (although through the land distribution hardly existent anymore) to open and to intermingle with other cultures, nationalities and ethnicities (predominantly Baluchi, South Asian (Indian, Pakistani, Sri Lankan, Bangladeshi), African).



0530 Past and Present in comparison

Based on analysis of the previous chapters, the natural, built, and human environment correlations and their strategies are explored in the following section.

0531 Urban system correlations and strategies

The case of MFA: Urban correlations of natural, human and built environment of the traditional oasis.

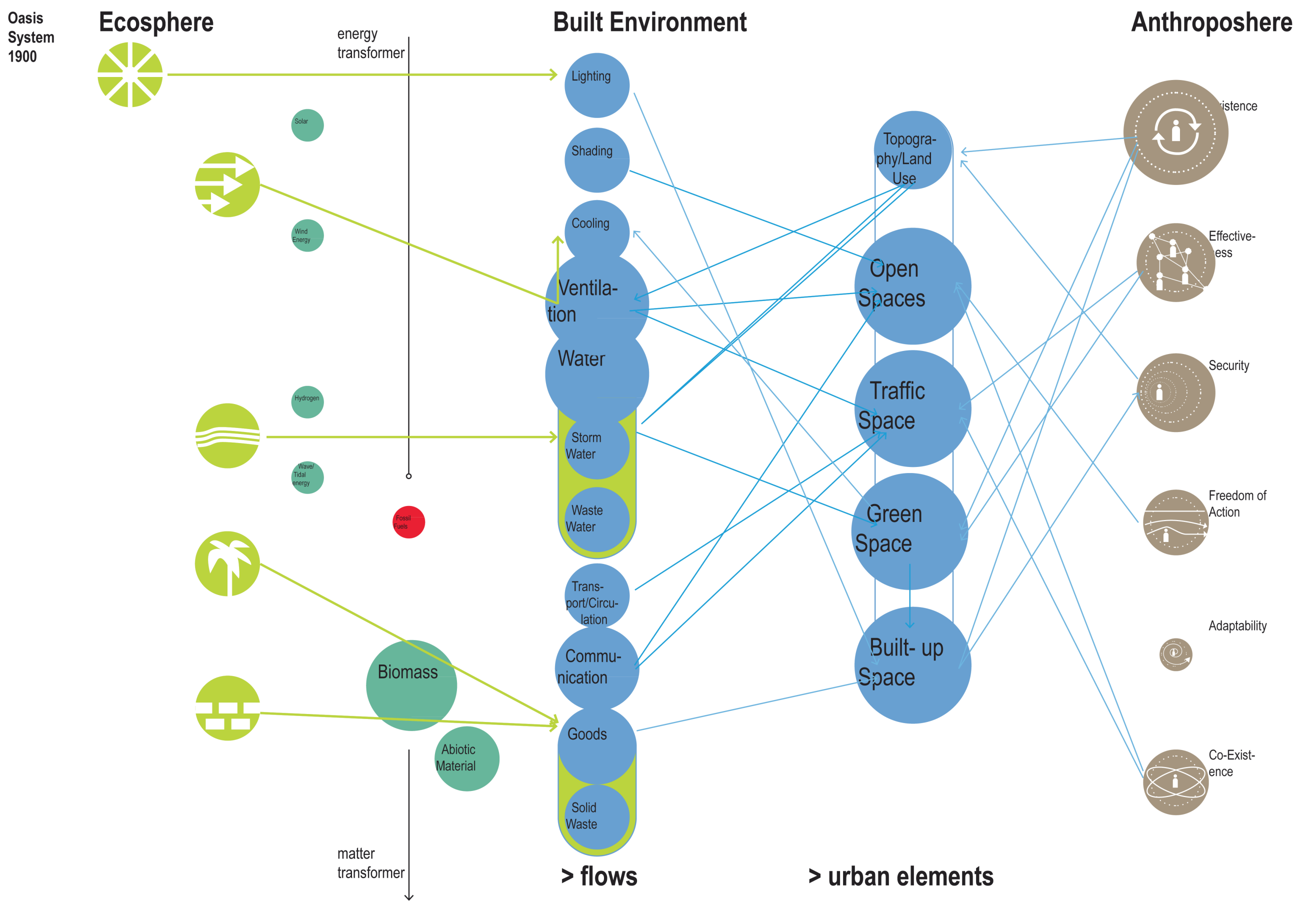


Figure 52→ MFA Urban scale: natural, built and human environment interconnections

Figure 52 depicts the linkages between the natural resources, flows, and elements of the urban system and their conjunction to the human environment. The sizes of the bubbles depict the strength of the interconnectedness from urban elements to natural and human ones. It becomes apparent that all available natural resources are connected to the urban flows, which again shape the materialized level of the urban layout. Water, goods, and ventilation are highly connected to the spatial elements. Furthermore, water and goods/food systems operate in closed cycles. Landuse seems to be less connected to the natural resources, which on the other hand enables the existence and security of the human environment. The interconnectivity levels of the human system ensure existence, effectiveness and security, but seem to lack the possibilities of adaptability, due to missing the opportunities to evolve further than the effective existence.

Land Use/Zoning: The zoning inside the clustered settlement is closely connected with the areas of effectiveness of the agriculture-based livelihood for survival in an oasis settlement. It also ensures communication within the socio-cultural circles of the community. Therefore the semi-private square close to the mosque and the *sabla* are located in the centre of the oasis at the t-junction of the main thoroughfares. Around this communal nucleus spread the residential zones, along the main axes of the connection network of co-existence to the neighbouring oasis clusters. The formal meetings of men in the mosque and the *sabla* allow the creation of policy and decision making, which determines the effectiveness of their oasis settlement.

Strategies used: 0334 adapt→ The integration of the community and the natural preconditions in order to enable co-existence in a self-regulating equilibrium of natural resources available, according to the needs of the community living in the oasis. It is self-regulating up to a certain extent of the carrying capacity of population and its immediate available resource network. Obviously this system has no means to grow beyond the available resources of the water driven environment.

Open Space: The ‘left-over’ spaces within the urban fabric those allow for socio-cultural actives (e.g. Celebrations) and therefore freedom of action to fulfil the cultural heritage and religious aspects of the community. Those spaces are the second communal level of public gathering after the semi-public/private courtyards inside the buildings. The co-existence of the built environment draws upon these open spaces.

Strategies used: 0332 respond→ Open Spaces respond to the given microclimatic conditions and at the same time to the socio-cultural flows.

0334 adapt→ In order to enable the self-regulatory framework of the communal co-existence.

Transit Space: As thoroughfares, roads would be left-over spaces between the buildings connecting the gates of the walled environment, which have been strategically positioned at the main connection points to the surrounding trade hubs of the market spaces in the north, and the main trading route towards the ports of the east coast of Oman towards the south-east. Those major trading routes are mainly following the wadi flows and therewith the main ventilation corridors through the landscape. Hence the shaping of those layers that enable transport and communication are closely connected with the access of the single residential zones and are furthermore used as the ventilation artery within the urban network. Hence the main thoroughfares are directed into the wind direction of the cooler winds in summer to ensure ventilation and cooling of the urban fabric.

Strategies used: 0332 respond→ Transit spaces respond to the given microclimatic conditions and at the same time reposed to the socio-cultural flows.

Green Space: The crucial feature of all existence in an oasis draws on the livelihood of the surrounding agriculture, which is powered through a network of irrigation systems. This landscaped productive element also contributes to the income and effectiveness of the oasis. It is the engine of the population yet at the same time the population is a very part of this whole interconnected system. Here the cycles of water, wastewater, goods, and waste are closed. Furthermore, beyond the life assuring wealth of production land, it also changes the microclimate of the nuclei of the built environment to a more beneficial environment for the human being.

Strategies used: 0331 secure→ Agriculture secures food, goods and energy.
0332 respond→ Field layout responds towards enhancing the micro-climate of the built up spaces; conservative use of water through grey-water cycles; recycling of waste as fertilizer for the soil.
0333 protect→ Self-sufficient farming through effectively layering plant types; efficient layout of irrigation systems according to topography and man made terraces.

Built-up Space: To insure the basic shelter of the human existence and to protect against external factors the building typologies used in oasis systems reflect the bioclimatic impacts of sun, wind, locally available construction materials and the anthropological needs of the social-cultural environment of a Muslim society.

Strategies used: 0332 respond→ Architecture responds to the socio-cultural need of the ascension of spaces from public to private, as well as to utilizing natural ventilation.
0333 protect→ Buildings protect the inhabitant from external preconditions (heat, light, precipitation).
0331 secure→ Built up space enables the existence of shelter, food storage, healthy/hygienic environment.

Lighting/Shading: Compact clusters reduce the impact of heat and light irradiation.

Strategies used: 0331 secure→ Reduce impact of heat and light.

Cooling/Ventilation: The building massing effectively enhances the cooling effect inside the urban fabric through the creation of draft channels, thus actively shaping the flow volumes in an urban and architectural scale of the main wind direction. In addition the agricultural belt creates a slight modification to the microclimatic temperature and humidity through a wind-chill effect of the organic compounds. All of these passive strategies help to create a minimally cooler therefore more comfortable spatial environment.

Strategies used: 0334 adapt→ The integration of urban features and the building shape supports a self-regulating ventilation throughout whilst adapting to the given climate condition. Passive climate engineering is employed.

Water Cycling: Water is the reason for the existence of human, animal and plant life in an oasis. Thus every drop is used effectively for humans and animals first, and their grey water is further distributed to the organic farmlands. Once drawn out of the falaj systems it is cycled back onto the aquifer of the wadi system through various filters of the human system to ensure existence.

Strategies used: 0331 secure→ The use of water is limited through effective reduced use.
0332 respond→ Grey water is recycled into the farms.

Goods Cycling: Food from the farmland and livestock is held inside the built cluster, which ensures the existence, creates employment, and offers resources of trade. Food and goods draw directly from agricultural products and by-products, which are cycled back as wastes into the agricultural system where they become organic fertilizers for the soil.

Strategies used: 0333 protection→ Cultivation of the sensitive farmland through various interconnected, effective measures: horizontal layering of shade, flow rates of *aflaj*, preservation of life-cycles of plants through the engineering of symbiotic relationships of plants, and back-cycling of organic waste as fertilizer to the soil. Thereby a higher efficiency of food/good cycling can be achieved.

The case of MCA: Urban correlations of natural, human and built environment of the current peri-urban sprawl of Muscat Capital Area MCA in the example of Al Khoud.

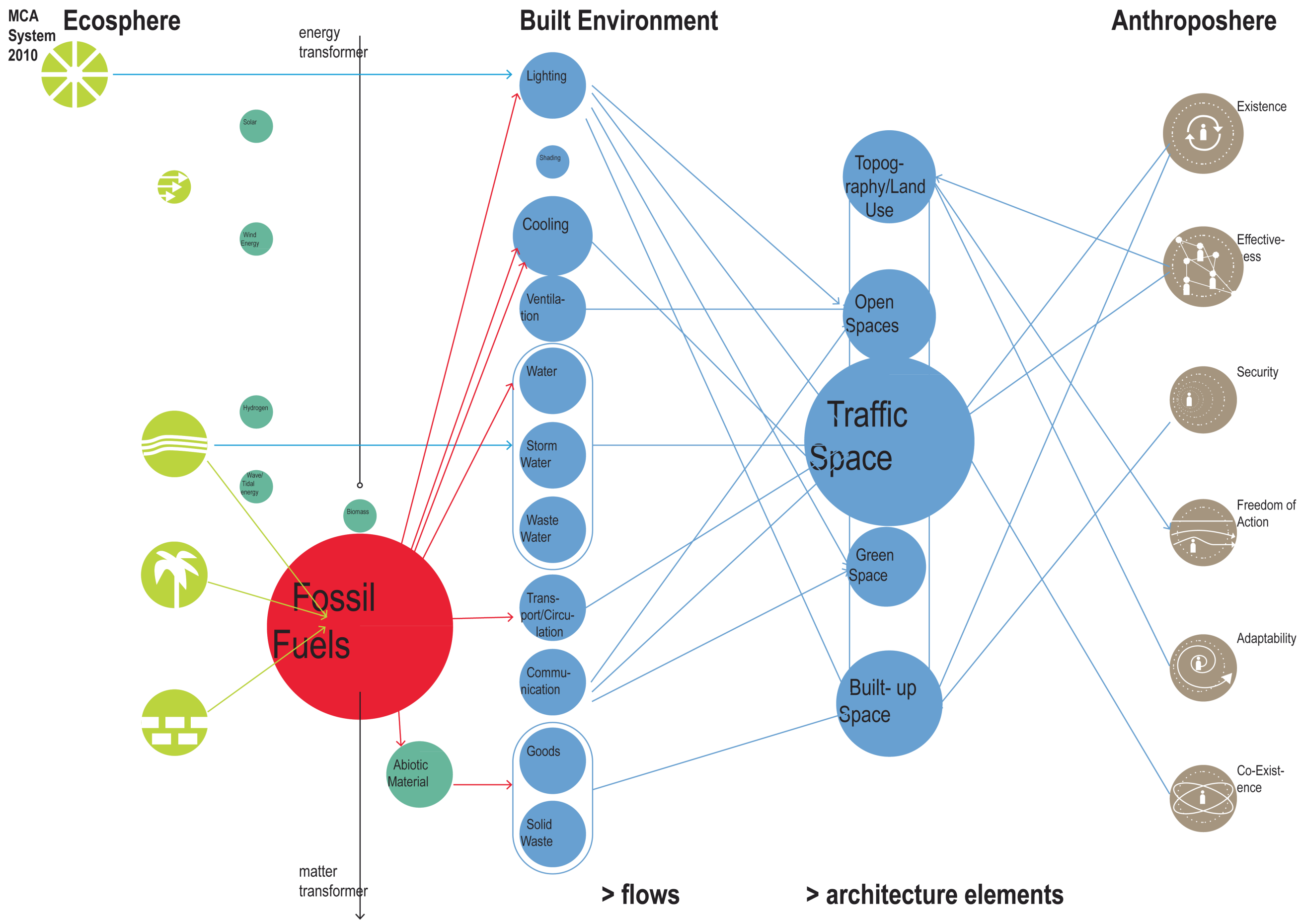


Figure 53→ MCA Urban scale: natural, built and human environment interconnections

In contrast to the oasis of the past, Figure 53 shows the direct dependency of the urban system on fossil fuels. Biotic and abiotic matter enables all electricity-powered devices for lighting, ventilation, transport, goods, and even for the making of water. Due to fewer connections amongst the urban flows and elements, transit space is the main corridor of distribution of urban flows and human needs. Most of the infrastructural entities are directly dependent on fossil fuels as is the built-up space. All human needs seem to be connected to the urban environment in varying degrees. The available natural energy resources like solar power, wind energy, hydrogen, and even the direct use of abiotic materials are not utilized in the present day urban environment of MCA. Additionally, water, ventilation, and waste are not linked to metabolic cycles. Land-use is disregarded to the prevailing topography and resources and only geared to serve the effectiveness, adaptability, and freedom of action of the human system.

Land Use/Zoning: The zoning of the wider area of the Muscat Governorate's Supreme Council of Town planning is established in a framework of separated singular uses of land. Hence residential, commercial, industrial, healthcare, governmental, and hospitality zones are dis-connected via vast high ways into segregated parcels of land. Those providing the basic needs of existence, effectiveness, and security on a bigger scale are not related to a human neighbourhood scale. Changes of the constitution into a monarchy, and the resulting land use policies, are de-marking property for singular owners. The previous existing communal ownership and self-regulative policy of the tribal settlement clusters have been overwritten by a national governmental constitution issued in 1970. Allocated to this constitution is an authority that now allocates land and its use in a top-down manner without considering the inherent communal connections of the tribal relationships.

Strategies used: In terms of a description of strategies inherent in the natural systems, as discussed in chapter 0300, a static system can be denoted as the most basic and non-responsive of all system hierarchies within the surveyed area. The only land-use responding to the security of existence and freedom of action can be observed in the allocation of the mosque and a small food shop next to it. Other facilities concerning education, health, employment, waste management, and energy transformation lay outside the evaluated radius.

Open Space: Apart from the neighbourhood mosque square that is only accessible for men, there are no allocated open spaces for communal activities in the area of Al Khoud.

Strategies used: 0331 secure→ the religious freedom of action for men.

Transit Space: The main artery for connections to water, food, communication and waste encompasses the street network in the area. The hierarchy of land and plots accumulate as secondary along the road network. The corridors allocated to roads are a major consumer of land. The layout of the network is not connected to bio-climatic consideration I.e. Shading, ventilation, airflow, etc. On a human level the road access and network enables basic existence, effectiveness and freedom of action. Transport is based on basic cars and trucks. No public transport systems like trams, buses, or railways are available.

Strategies used: 0331 secure→ all flows of natural resources into the neighbourhood, securing of waste management, basic enabling of social co-existence and adaptability are enabled through connecting corridor of a road network.

Green Space: As prevalent in the example of Al Khoud discussed, there is no productive allocated agriculture linked to the neighbourhood environment. The direct link of agricultural land is spread onto a wider regional and international level. Hence most of the consumed products of food and livestock are either internationally imported, or to a minimum consumption rate produced in the Al Batinah region (200km distance) or in the Dhofar region (1000km distance).

Strategies used: In terms of a description of strategies inherent in the natural systems as discussed in chapter 0300 a static system can be denoted as the most basic and non-responsive of all system hierarchies.

Built-up Space: Disconnected to the immediate bio-climatic and socio-cultural conditions, the building typologies of residential, commercial, industrial, governmental, religious, and healthcare facilities are composed of free standing solitaires on vast plots surrounded by boundary walls to ensure a level of security.

Strategies used: secure 0321→ Although not responding to any environmental factors, the built-up space secures the existence of its inhabitants.

Cooling and Ventilation: Urban ventilation and cooling are not considered in the planned layout of the area. Prevalent winds from the wadi system are not utilized in the urban morphology, given the fact that the buildings are assembled as disconnected climate capsules that use electrical powered air conditioning to achieve a 'comfortable' indoor climate.

Strategies used: All bio-climatic non-adaptable measures of the envelope are compensated by the use of energy consuming devices.

Water and Sewage: The water, as well as wastewater, is delivered and collected separately to the system of Al Khoud. Water trucks that draw the potable water from desalination plants in the region feed the water tanks on top of the buildings. Sewage is then accumulated in septic tanks and re-transported for treatment or direct landfill.

Strategies used: Deployment of fossil water and energy for desalination.

Goods and Waste: Goods are all imported into the case study area of Al Khoud. The road network enables transport modalities for goods and a small supermarket serves the community of Al Khoud to a certain extent. Some 20km away, a bigger shopping mall serves the major goods distribution of the residents. The resulting waste is collected in stationary containers that are transported to landfills without any waste separation measures.

Strategies used: Transport to import goods and food and transport to collect waste into landfills.

0532 Architectural system correlations and strategies

The case of MFA: Architectural correlations of natural, human and built environment of the traditional oasis.

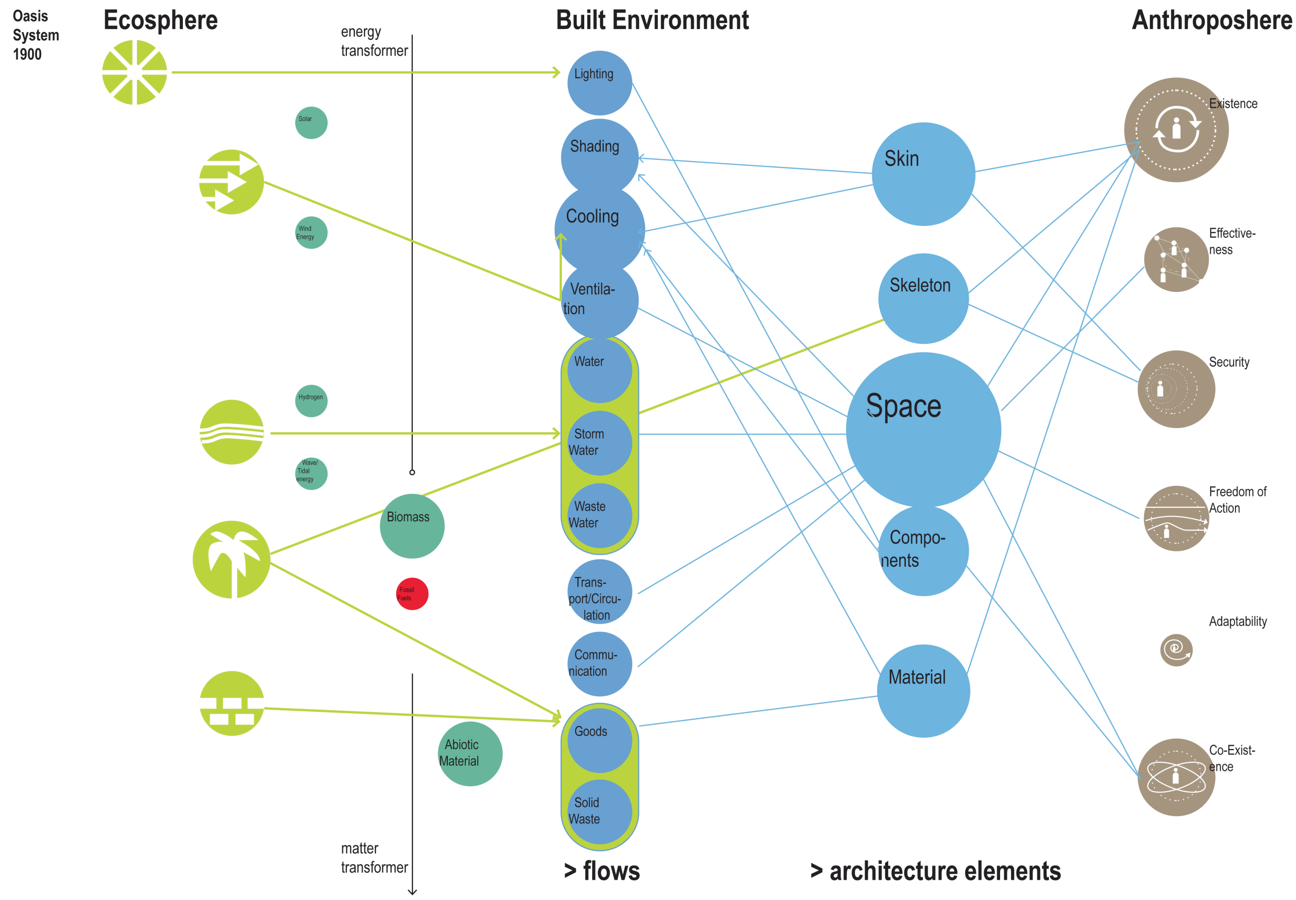


Figure 54→ MFA Architectural scale: natural, built and human environment interconnections

As illustrated in Figure 54, a high interconnectivity of natural resources, human needs, and the built environment was essential for the traditional oasis settlement. The given conditions of natural resources; namely water, prevailing winds, the solar impact, and biotic and abiotic materials were used to create an advanced environment for the human being to survive in the harsh and resource scarce environment of the desert. All of these factors were carefully considered and logically put into passive design strategies in order to engineer the natural given surrounding into a habitable entity. Almost all building elements, especially the spatial programming, have considered a direct link to human needs and environmental conditions.

Skin: Locally available construction material blended into the surroundings and was constructed with low energy consuming measures. Additionally, the reduced façade design reflects the preservation of socio-cultural aspects of privacy and the massive, almost fortification-like envelope protects the structure from intruders.

Strategies used: 0332 respond→ Locally available material mimics surroundings as well as needing fewer maintenance and construction works.
0333 protect→ Secure the privacy of the inhabitants.

Skeleton: The solid construction of walls and the filigree construction of slabs and roofs allow a durable massing, which the structural design depends on the materials used. Hence, the spans of rooms could only reach up to 3.50m according to the length of palm-tree trunks, and heights according to the structural tilting ratio of the stone or loam blocks.

Strategies used: 0332 respond→ The building structure responds to the statically available resources of the surrounding area. The pragmatic direct translation from material to shape reduces the impact of required energy.

Space/Programming: Positive space serves the flows throughout like ventilation, water, and circulation for the benefit of the inhabitants' communication, existence, and cultural belonging.

Strategies used: 0334 adapt→ Positive spaces do not only integrate bio-climatic needs but at the same time anthropogenic needs are met. These allow the co-existence of various functions and aspirations whilst adhering to environmental limitations.

Components: Filled-in components like wooden shutters, doors, and niches have manifold functions: Shutters are ventilations slits, inviting the occupier to look through, but they are not see though from outside. Also the decorations represent the regional influence and tell stories of the inhabitant's travels or trading business. Niches take away weight from the load-bearing walls, and yet provide shelves and cupboards. The volume also acts as a lampshade for the sparse light that is let inside.

Strategies used: 0332 respond→ Components respond to their requirements with a high flexibility to a multi-faceted usage of the same unit.

Materials: The use of locally sourced materials is limited to the available properties. The durability of buildings depends on the quality of the lime plaster and mortar (see *sarouj*). Nevertheless through the ability of cycling and re-use, materials do not comprise the basic principle of static systems.

Strategies used: 0321 secure→ Reduce dissipation of material through cyclic reuse of materials.

Lighting/Shading: Limited perforations to the thermal mass for outside elevations. Shaded courtyard area inside allows big openings and spaces.

Strategies used: 0321 secure→ Reduce impact of heat and light.

Cooling/Ventilation: The building volumes and ventilation slits enhances air-movement through the compact volumes. The materials used enable a wind-chill effect.

Strategies used: 0324 adapt→ The building shape and materials used support a self-regulating ventilation throughout whilst adapting to the given climate conditions.

Water Cycling: see description on urban scale.

Strategies used: 0331 secure→
0332 respond→

Goods Cycling: see description on urban scale.

Strategies used: 0333 protection→

The case of MCA: Architectural correlations of natural, human and built environment of tof the current peri-urban sprawl of Muscat Capital Area MCA in the example of Al Khoud.

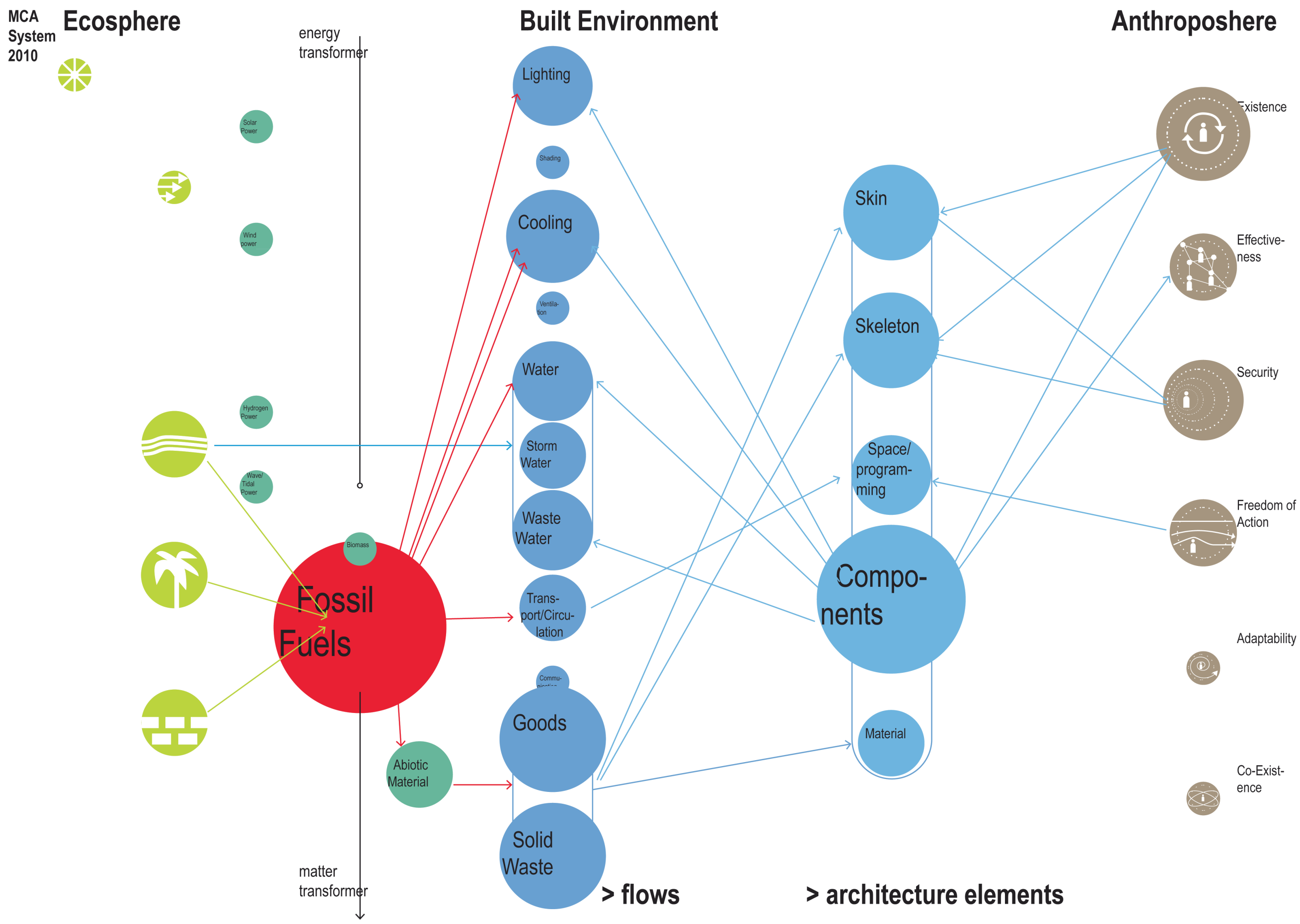


Figure 55→ MCA Architectural scale: natural, built and human environment interconnections

Figure 55 explains the utter dependency of the built environment on one resource only: fossil fuels. The human system depends on an architectural scale, mainly on technologies that condition the interior climate to the desired amenity. Fossil fuel transforms not only the electricity needed to power all those technologies; it is also the main converting factor to produce potable water from saltwater. Most of the building elements do not react in any way to the natural environment but solely on the economic ability to supply goods via transport networks, again powered by fossil fuels.

Skin: Apart from the light-reflecting colour, the envelope of the building does not adapt to the bio-climatic influence or the socio-cultural policy of internal private life. This is further compensated through a two-meter high wall that again protects the freestanding building from the public realm.

Strategies used: Expression of individual preference of design regardless of the urban, human and natural environments.

Skeleton: Concrete is the predominant resource of which the reinforced frame, concrete block infill, slabs, roofs, and finally the plaster is constructed. Due to this composite construction method there are hardly any restrictions to sizes and shapes of building components. Hence non-compact forms are possible.

Strategies used:	The opposite of responding to bio-climatic impacts. Rather the expression of the individual is encouraged according to economic possibilities, which can be analysed as strategy here.

Space/Programming: The accumulation of spaces according to the social-cultural needs of the inhabitant. A clear separation of women, men and servants spaces enhance the segregation of co-existence.

Strategies used:	0331 secure→ Separated and mono-used spaces according to basic existence factors.

Components: Since most of the fit-out components are also imported, the selection is limited to the supply. Mainly plastic or aluminium framed windows and doors are offered. Contrary to the outside appearance, the huge openings are covered from the inside due to privacy reasons and artificial light is favoured over natural light (see survey description in →0410).

Strategies used:	The selection and design of components depends on the reasoning and decision of the individual alone. It is more a question of expression and economics rather than of fulfilling any human systems principles.

Materials: Most of the materials for components are imported and hence, apart from the construction energy costs, also contribute carbon emissions for transport. The composite of steel reinforced concrete dissipates mostly as landfill, and an after usage is only feasible through the massive input of energy.

Strategies used:	The opposite strategy to possibilities of material recycling or re-usage is apparent here.

Lighting/Shading: Big openings and no external shading devices lead to an extensive use of air-conditioning behind the un-insulated walls to combat the heat intrusion. Inside covers of openings hinder the intrusion of daylight.

Strategies used:	All bio-climatic non-adaptable measures of the envelope are compensated by the use of energy consuming devices.

Cooling/Ventilation: The buildings interior climate is treated as a self-contained microclimate separate from the surrounding bio-climatic factors. Apart from the high energy consumption of compensation technologies, this also causes hygiene issues inside the climate bubbles.

Strategies used: Energy consuming technology instead of passive strategies.

Water Cycling: see description on urban scale.

Strategies used: Deployment of fossil water and energy for desalination.

Goods Cycling: see description on urban scale.

Strategies used: Transport to import goods and food, and transport to collect waste and carry to landfills.

Comparison Water driven versus transport driven environment

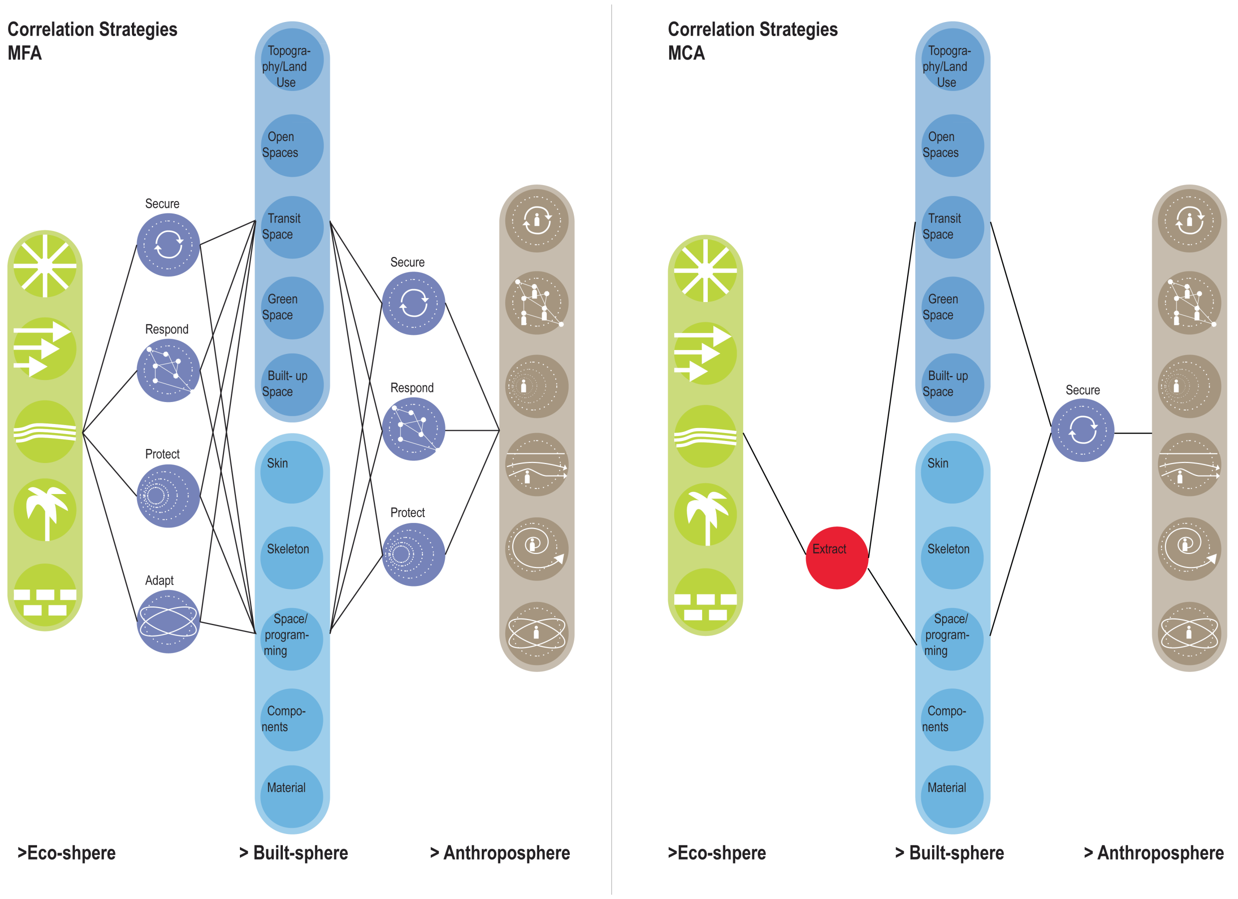


Figure 56→ Comparison MFA and MCA regarding employed correlation strategies

A concluding diagram of interconnectivity between the available natural resources, urban elements, and the human environment (Figure 56) is used to compare the strategies of connections, which are prevalent in the traditional oasis systems of Al Mansafah (MFA) of the past, and the current built environment of the Muscat Capital Area (MCA).

According to system principles (→0320) the viability of a living system depends on the connectivity of its elements. Obviously the case study of MFA has a much higher inter-connectivity of urban and architectural factors to the human and natural surroundings. Whereas in the study of MCA limited connections and strategies are used to bind a built environment into the surrounding factors. It also becomes prevalent that MCA does not establish any feedback loop to the necessary resources through the according system strategies, but only at this current state uses a linear strategy that extracts resources and secures human needs. In order to achieve a viable urban system that has the ability to flexibly adapt to bio-climatic and socio-cultural circumstances, the current situation of MCA could learn from the strategies that were used in MFA:

1. The securing of resources for existence through reduced use according to availability.
2. Responding to the Eco- and Anthroposphere through conserving communal needs and the reuse or recycling of biotic and abiotic wastes as resources for the regeneration of farm lands and built up space.
3. Protecting the cultural heritage and co-existence of peoples through applying spaces and structures in the urban and architectural scale. Additionally, the preservation of the eco-sphere through effective cultivation of resources.
4. Adapting to bio-climatic conditions through utilizing the built environment as an integrated system that elongates and equalizes natural resources for the needs of the human being through passive strategies.

In comparison the following topics evolve for future development:
Community: Contrary to the Arabic-Islamic principles of architecture as described in →0523 the MCA urban layout of scattered solitaire footprints on disconnected plots of land, the relationships amongst neighbours via communal spaces and the self-management of streets by their local inhabitants are not given. It relies purely on the hydro-carbon driven power grids to condition the interior spaces to the desired climate bubble. Hence building shapes, orientations and considerations of other bioclimatic aspects are entirely disconnected.
Goods/Food: Whereas in MFA the built environment was dependent on the agricultural context of its farmland belt of various immanent system components, MCA is contracted as a conglomeration of individualized climate capsules that are fed through the import of goods and infrastructural services.
Water: Arid hot desert environments are driven by the most precious element of water. Surely the demand, due to population increase, exceeds the availability of water resources that are mainly from non-renewable fossil water resources (which are currently exploited in the Al Batinah region of Oman to cover some regional agricultural products). The carrying capacities of oasis systems are

limited; hence the size of the population and thus the built environment must not exceed the given flow of resources. These days fossil fuel driven power makes the desalination of saltwater possible under a huge accumulation of GHG emissions. Hence technologies have to be introduced to nurture the demand of fresh water by using strategies for technologies that are directly connected to readily available resources like solar energy. Additionally, the feedback loop of cycling precious water needs to be explored.

Materials: Other integration strategies, especially regarding the local abiotic materials and their conversation to useable building materials, should be considered through learning from the oasis systems. Obviously construction materials of the past do not meet present requirements in terms of durability, strength etc., and the needs of the 21st century policies. Still, through further research and development local resources can be converted via renewable energies to products for the use of the built environment.

Waste: The main characteristic draw on the abundance of direct links to local natural resources is the cycling of wastes back into the system in MCA. Therefore the transportation system is the only security that enables the import of water and goods into the fabric and the export of wastes out of the secluded car based sprawl. Circular metabolic flows have to be encouraged, as they were the foundation of the functionality of the oasis system.

Thermal Mass and Insulation: The isolation policy goes beyond the societal fracturing of tribal entities into a dependence of mainly privately held companies providing those required infrastructural services. This therefore makes the MCA settlement a highly dependent monoculture that seems almost the opposite of the principles of natural systems. Urban futures that thrive towards levels of integration, adaptability, and thus 'sustainability', are unlikely to survive this disconnected approach and consumer-oriented method of city making.

Green Space: MCA decorative landscaped areas are visible as linear gallery products next to the main highways. Green space as a sign of luxury and wealth has become the decorated frame of highways. On the other hand every drop of water in MFA has been used for irrigating plants in order to survive with a productive landscape in the midst of a desert. This direct dependency needs to be understood and dealt with in order to overcome the high dependency on centralized units of water desalination plants, landfills, and water treatment plants powered through fossil fuel powered transport systems.

Built up space in MCA is also driven by a massive consumption of land in terms of a horizontal spread, resulting in huge surfaces bound to heat island effects, albedo[36] effects, cooling needs, and connection needs via transport systems. MFA and other oasis systems have used the closeness of the built structure to minimize the surface available towards the harsh sun irradiation and

[36] From Latin 'albedo': the reflecting power of a surface

thus causing unwanted heating of thermal mass. MCA compensates with five elevations to be cooled down via air conditioning systems. In general, 70% of the power consumption of buildings is being used for air conditioning alone.
Apart from those ecological consequences, the MCA building also reflects a change of the social layout of spaces compared to the one in Mansafah where multifunctional spaces contribute to the flexibility of the building (for example the residential mansion that was also used as a hospital). A clear and static irremovable arrangement of the rooms leads to a segregation of men, women and servants. Common spaces are used more as circulation spaces rather than gathering opportunities. The introduction of split unit air-conditioning in every room has also led to an inflexible system of static spaces, whereas previously people would move to different rooms in the house depending on yearly seasons and daytimes.
Skin: The quest for communication seems to be currently overcome by eclectic decoration features and facades that express stories of a seemingly extroverted society. In the same time the façade does not reflect the introverted social environment, which covers all the openness to the outside again from the inside, and leaves the decorated shed as an energetic problem to be solved by the right technology.

0540 Lessons learned from past and present for the future

Major observations and development patterns are summarised in the following as result of the comparison between the two case studies of the present day settlement Muscat Capital Area MCA and the traditional one of the past Al Mansafah MFA.
MCA: Renaissance and dependency
As previously highlighted in the introduction to →0500 the present day settlements in Oman has been subject to substantial social, political, economical and environmental change since the introduction of a new government system in the 1970s. Self-regulatory responsibilities of tribal land were altered to an ‘all land is government land’ policy that forced the traditional knowledge to organise societies and utilise land according to an environmentally (natural and human) appropriate manner to relinquish. Not only direct responsibilities to preserving the surrounding ecosystem of the place, but also the socio-cultural connectivity to those places remain a mere memory to the elders. The present day education system does not allow traditional knowledge and historical development (before the introduction of the ‘Renaissance’ in 1970) into the curriculum. A continuation and transfer of such integrative knowledge over the centuries is officially interrupted and replaced by imported practises, ‘western’ education, handicraft, industries, services and goods.

In order to relocate people from remote places to the metropolitan area, distribute them via lottery, into low density, horizontally sprawling residential areas infrastructure became the backbone and driver of the present day urbanisation. Respectively (also through the convenience of redundant hydro-carbon resources) MCA entirely depends on fossil fuels to convert energy and materials into the flow of infra-structural services.

As of 2012, never since the 1970s have so many infrastructural projects been underway in the history of the country with a current population of 3 million over an area of 300,000 sq km. Oman's future expenditures include more than $78bn for infrastructure projects by 2016 (Construction Week Online, 2012 October 3). Apparently the 'safeguarded' reliance of hydrocarbon fossil-based resources embeds the decision makers of this ongoing urban sprawl in a short-sighted cloud of security. Therefore, it is not surprising that the most connected urban element in MCA remains to be transport space, thus nurturing all the resource inputs and outputs as well as anthropological aspects of existence, effectiveness, freedom of action, adaptability, and co-existence.

The intend to mix up family backgrounds, diversify society and end self-organised family/tribe structures lets the government become the well-fare state that every citizen depends on.

All other urban elements are a result of the road networks that determine allocated land-uses, built-up spaces and open spaces. Within the urban framework, green spaces for productive landscape are not foreseen. A mere water-consuming decorative strip of greenery (mostly non indigenous species of e.g. turf) for the governmental declared law of 'beautification' can be observed along the major road arteries.

MFA: Integrated web of the oasis

On the other hand, in the oasis town the transit spaces consist of left over built up spaces that ensure co-existence and trade (effectiveness) of the inhabitants, but which are purely based on non fossil-powered ways of transport via animals or purely pedestrian means. Surely those ways of transport are not transferable into a 21st century urban setting. Yet still there is further evidence of a transit space exceeding the encapsulated put-through of traffic can be seen in the communal levels of communication (I.e. Pedestrian, cycling opportunities, that have to be climatically challenged) and the concept of 'left-over' space between built, open, and green space. Another aspect of communal life that ties together the self-regulating process of a community in MFA can be identified in the open spaces.

Overall, despite the very sensitively connected parts of the human, natural and built environments of the oasis, it needs to be noted that the function of the anthropogenic need of adaptability through the evolution processes of creativity, training, and entrepreneurship are not given in the case study. This also shows that through the import of socioeconomic change the oasis, as the system, which existed before the 1970s, has not survived. To date, most of the traditional oasis

towns have been devoid of human activity and hence are bound to deteriorate entirely due to not being maintained.
The case of Al Mansafah (MFA) as the old centre of the Ibra region is a case of an alarming regression from a prosperous hub to a ghost town: everywhere abandoned and therefore collapsing houses, degenerated community spaces, and the lost cultural and social life of the last inhabitants with no income opportunities. The broken *aflaj* system sums up the symbolic picture of Al Mansafah's situation: Instead of shadowed fruitful gardens, dead trunks of palm trees lay in desolated territories.

Interpretation of the tradition of the past and the needs of the present: system model of the future

> *'No neighbourhood or district, no matter how well established, prestigious or well heeled and no matter how intensely populated for one purpose, can flout the necessity for spreading people through time of day without frustrating its potential for generating diversity.' (Jacobs, J. (1993). The death and life of great American cities)*

The dynamic nature of the morphology of the built environment can hardly be accommodated by either of the extreme conditions presented in the case studies previously examined, but should be responded to in a meaningful and appropriate manner: Hence maintaining, adapting or reinterpreting traditional structures through using the system's eminent strategies (→0330). New structures, policies and planning have to be developed for the emerging needs, considering the extreme challenges the current trend of urbanisation in Oman brings with it. Reinterpretation of traditions based on modern needs is a main consideration of this research, but in the same breath this extends the strategies that are analyzed in the retrospective case studies into a proposition for a higher connectivity of typological and morphological principles that also follow cultural and urban continuity, compared to the contemporary city-making in Oman and the wider region of the Arabian Peninsula.
After this analysis we can conclude that the past example shows a higher interconnectivity of natural, built, and human environments than the present day case study. Furthermore, four different hierarchies of strategies could be observed in the case of the oasis system in order to reach the interconnectedness: secure, respond, protect, and adapt.
The contemporary case of transport driven sprawl leaves us with the basic static strategy of the exploitation of the natural systems and the securing of the human needs hierarchies.
In the past, local resources were the foundation of survival. In the globalized present, they are replaced by hydro-carbons used as export goods in order to import foreign goods and food. Consequences thereof arise in conflicts of present urban sprawl mechanisms. In the future, the clock

cannot be turned back by reviving only single oasis components and turning them to symbols of our cities, which happens already: Symbols like palm trees are taken as a ‘greenification’ element, which are used for beautification applications but do not solve the general problems of exploiting our ‘spaceship earth’.
The use of devices, which work as “green-washing” products like PV-cells being taken as luxury symbols to indicate the “green” engagement of persons/ companies as a lifestyle brand, is also not reasonable. Certainly those measures support the sustainability (endurance) of economic growth - but not a balanced system of ecology, as long as devices are used which do not follow the rules of living system principles.
We cannot return to the past and implement traditional self-sufficient oasis system models into future urbanism. However, we can use the oasis as passive system models, enriched with active convertors of energy and materials that adapt to our current and future challenges.
Following the logic of system principles, the next chapter (→0600) proposes a matrix to establish the highest system connections between the ecosphere and anthroposphere. Strategic interrelations of those through-flows enable the built environment to act as a smart support system rather than an energy-eating and polluting technological apparatus.

0600 Correlation Model

Re-spective analysis (0500) leads to a pro-spective correlation model (→0600) for future comprehensive urban systems, using trans-spective system principles and strategies (→0300).

> *Interaction between energy systems and urban structure takes place at all spatial scales from the regional, city, and neighbourhood to the individual building (Owens, 1992, in Breheny, M. J., 1992, pp 81-82).*

Synopsis

The methodology of the previous case studies ended with analysis of applied system strategies in architecture and on an urban scale of past and present settlement patterns in the case of Oman as representative of developments on the Arabian Peninsula (→0530). Through system orders, which were established in chapter →0400, the respective elements and flows of a built environment and their relationship to the surrounding anthroposphere and ecosphere are discussed. Furthermore, the linkages are compared to the natural system of inherent strategies (→0330) to figure out the viability of traditional settlements in comparison to current development tendencies. What could be learned from the case study is that traditional settlements as a system worked on the basis of self-sustainability among a certain section of the population in conjunction with locally available resources. In terms of system hierarchies it compares to the current urban sprawl as a much higher connected and thus integrated and viable system. Obviously societal conditions (effectiveness, freedom of action and adaptability of the anthroposphere of the 21st century) have changed, so it would be romantic to preserve this traditional system without asking:

How can cities and architectures become support systems that have properties to co-evolve as cooperative sub-systems with the surrounding eco- and anthroposphere under the rules of ecology?

The further goal of this research shall be to resume an overall *Bezugssystem* (reference matrix) that enables adaptable, viable and thus ‘sustainable’ interrelations between the anthroposphere and ecosphere through the built environment as a support system for dynamic structures. The compilation of a correlation model (Correlator) as a network of relationships is set upon the following questions:

Why? What sort of functions and needs determine a built environment?

Anthroposphere (human system) →0410

What enables functions? Which elements and flows are to be considered?

Built environment (Urban, architecture and technological scale) →0430

Which resources are needed for the built environment?

Ecosphere (natural system) →0420

How to ecologically interlink the above?

Strategies for correlation →0330

What are the rules for the matrix structure?

System principles →0320

Accordingly the formulation of the matrix is developed in conjunction with eco-system inherent strategies (0330) as a toolkit to determine dependencies of sub-systems (0410, 0420, 0430). In →0610 the Correlation Model (Correlator) is formed on the basis of system principles →0320. The Correlator is further discussed in →0620 in general on a global scale followed by recommendations of exemplified at possible correlations of a desert oasis system in →0631 and at urban strategy complexities in →0632.

0610 Forming the Correlator

A city's life comes from its connectivity (Dupuy, 1991)

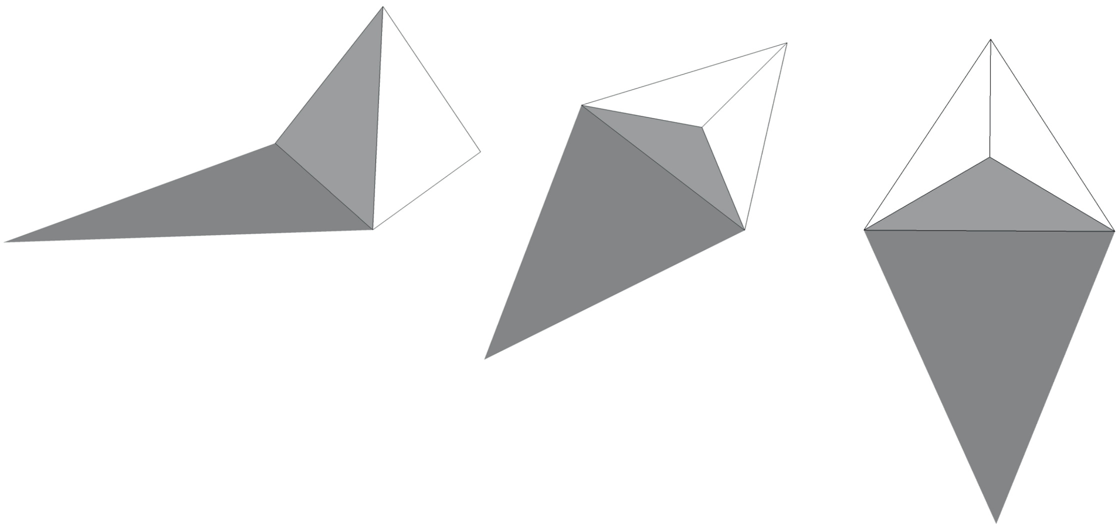
As discussed in →0100, the prevailing scarcity of resources and pollution debates have led to the quest for ecologically integrative development. Ecology, which deals with the relations of organisms to one another and to their physical surroundings, underlies certain principles. In order to integrate a built environment to its system boundaries of eco- and anthroposphere, it needs to adhere to the same principles. In doing so, urbanism and architecture become an integral part by acting as a regenerative organism of flows and elements. In an abstract model for thinking those ecological connections for the built environment, the human, natural and built environment dimensions shall be correlated via ecological system strategies. This results in a matrix of foremost four dimensions: ecosphere, anthroposphere and built environment connected via system strategies. The built environment per se is further broken down into the technological transformation processes that are inherent in urban scale and architectural scale. So, in total, six different dimensions, which all shall be correlated to achieve a higher connectivity amongst prevalent principles, flows and elements in a comprehensive network, shall be discussed.

3D correlation as thinking space

Those six dimensions are in this thesis considered as axes that equally contribute to the wholeness that lies in between. In a spatial application, six axes form a tetrahedron (see Figure 57). Every axis has its individual coordinates which all contribute to this bigger cohesive network of interdependent dimensions to produce highly ecologically interconnected urban and architectural systems. Also it is worthwhile noting that, whilst the axes of the ecological strategies, ecosphere and anthroposphere are fixed though principles as explained earlier, the fourth plane (in this case, the built environment) consists again of three axes where those principles can be applied. The volume of the tetrahedron automatically depends on all axes to be correlated thus in synergy. Buckminster Fuller praises the ‘six angular degrees of freedom’ in his writings in ‘Synergetics: Explorations in the Geometry of Thinking’:

> *Synergetics is a triangular and tetrahedral system. It uses 60-degree coordination instead of 90-degree coordination. It permits conceptual modelling of the fourth and fifth arithmetic powers; that is, fourth- and fifth-dimensional aggregations of points or spheres in an entirely rational coordinate system that is congruent with all the experientially harvested data of astrophysics and molecular physics; that is, both macro- and micro-cosmic phenomena.*

It coordinates within one mensurational system the complete gears-interlocking of quantum wave mechanics and vectorial geometry. (Buckminster Fuller, 1975, Section 202.01)



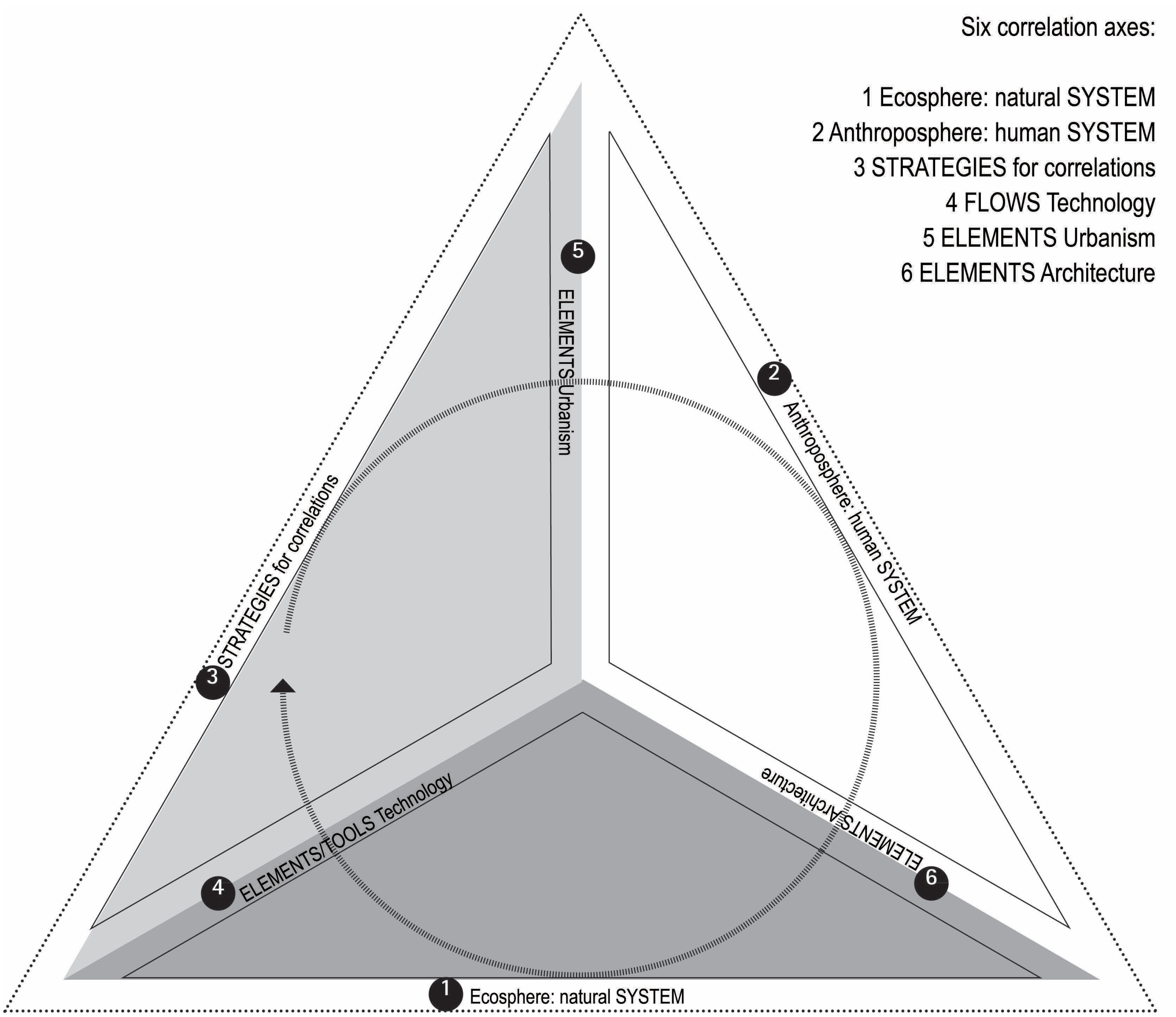


Figure 57→ Axes of the correlation model

Figure 58 gives an overview of how the contents of this work are connected to achieving a correlating matrix to support the inter-relational understanding of the built environment: The overall function or system periphery of the built environment consists of the human needs (anthroposphere) on the one hand (→0300, →0410) and the natural resources (→0420) of the ecosphere on the other. The compensation of the needs of the human environment through the use of natural resources concentrates in this work on the built environment[37] (→0430). In order to support the linkage between eco- and anthroposphere, the different scales of the built environment commence in between (axes urban, architecture and technology). Based on an analysis of prevailing ecological system principles (→0320), the most important part of the matrix answers the question of how those system elements and flows can be qualitatively connected in order to reach a high interconnectivity in the system boundaries. Hence, a sixth axis is reserved for correlation strategies (→0330) that finally form the Correlator as a network of relationships.

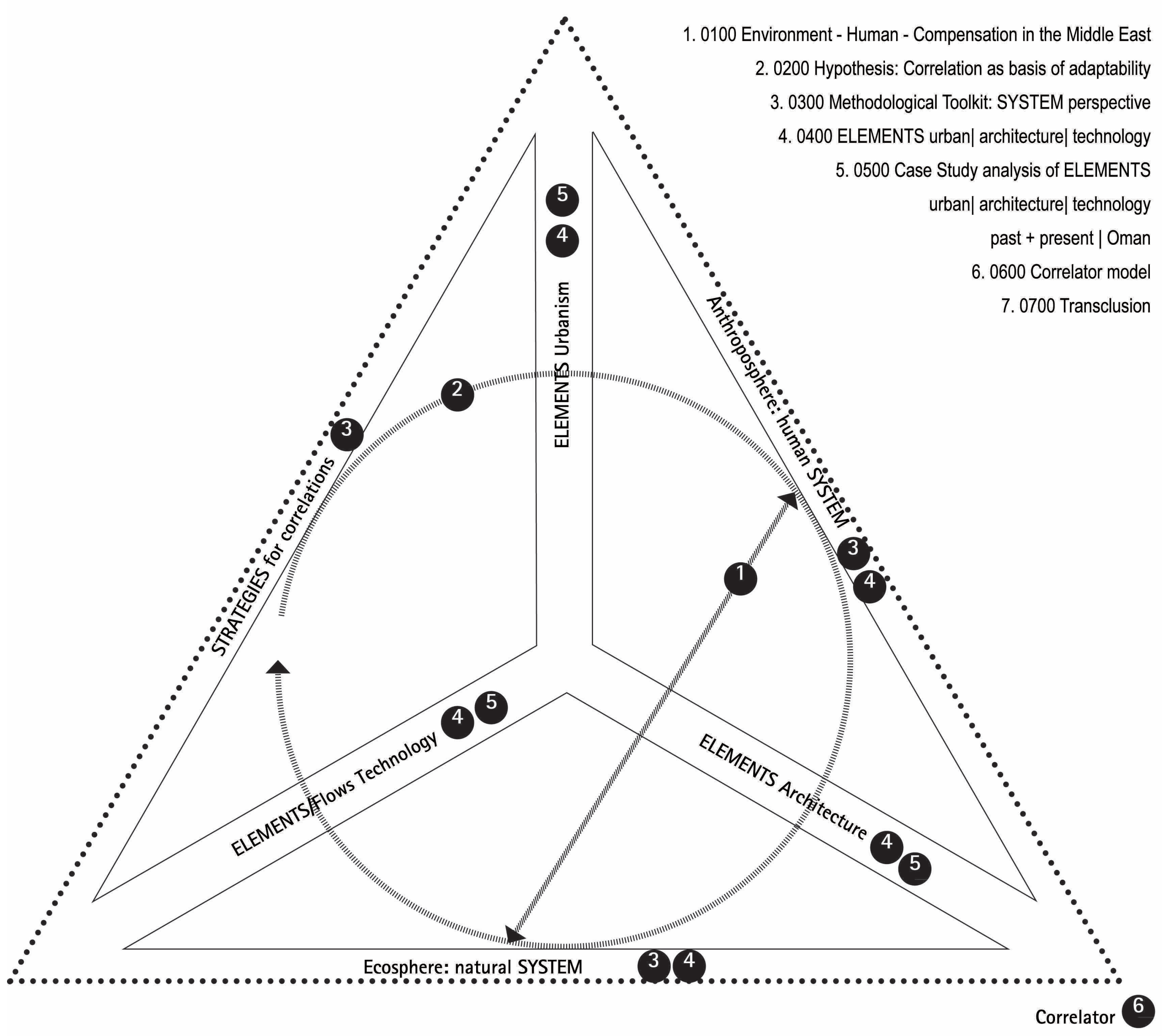


Figure 58→ Axes of the correlation model regarding chapter structure

[37] Other support systems could include governance, economy and society.

The argumentation in →0100 states the definition of the built environment as a support structure for the human environment within the natural environment. Hence the built environment spans between the human and natural environment and can be seen as the conditioning 'skin' between human beings and the natural environment. For our needs as human beings on this planet, the outcome of the built environment purely serves the functions and aspirations of the human system alone.
Certain complexity levels of the human system have been laid out and discussed (→0400). All resources are of natural origin and hence supply the support system of the built environment that again serves the anthropocentric approach.
The natural system as well as its sub-system, the human system, runs under the same hierarchies of system connection concepts. The use of those concepts as identified in →0330 have been devised and tested on case studies (→0500). They result in the assumption that the higher the complexity of the strategy, the higher connected are the flows and elements and hence the more viable and stable a system becomes in the long run.
For the proposed thinking model of a correlation system, those strategies comprise possibilities as to how different identified elements and flows of nature and the built environment can be interconnected.
The important aspect here is that there are no fixed recipes for the connection of elements and flows of the different axes presuming the correlation matrix in itself as a flexible open system.
So, the approach used to correlate these axes can be a mere dynamic one without giving any limitation or restriction to the use. Therefore, at this point, the author wants to point out that the emphasis in the proposed model lies in its qualitative aspects rather than quantitative measurable fixed connection.

Hence the forming of the relevant axes in the next step can only comprise a mapping of system boundaries and that the flows that are shared in the same subsystems.
In other words, the goal is to establish a correlation model of relevant areas in conjunction with each other in order to provide the freedom of inter-connections between those mapped areas for any user. Those users could be any decision-maker, designer, planner, analyst etc., who wants to systematically connect the natural, human and built environment. The starting point of the investigation should also be left open for a decision as to whether connecting natural flows to buildings or streets to human co-existence is better. Therefore, the shape of the matrix needs to be non-hierarchical whereas six axes have to be able to be connected to each other.
In chapter →0630, recommendations will be given on the specific application of strategies as examples to reach higher adaptive, and hence viable, urban and architectural environments. But this Correlator shall not be limited to suggestions only.

Forming the Correlator upon the rules of ecological systems:

Beyond the synergetic results of a tetrahedron as an abstract thinking space to correlate six axes, other principles inherent in an ecosystem verify the organisation of correlating the discussed areas. Here living system theories principles after Capra (→0320) provide a 'Bauanleitung' (instruction manual) for viable systems. In the following section, those principles get transferred and applied to the built environment in conjunction with the human and natural environment:

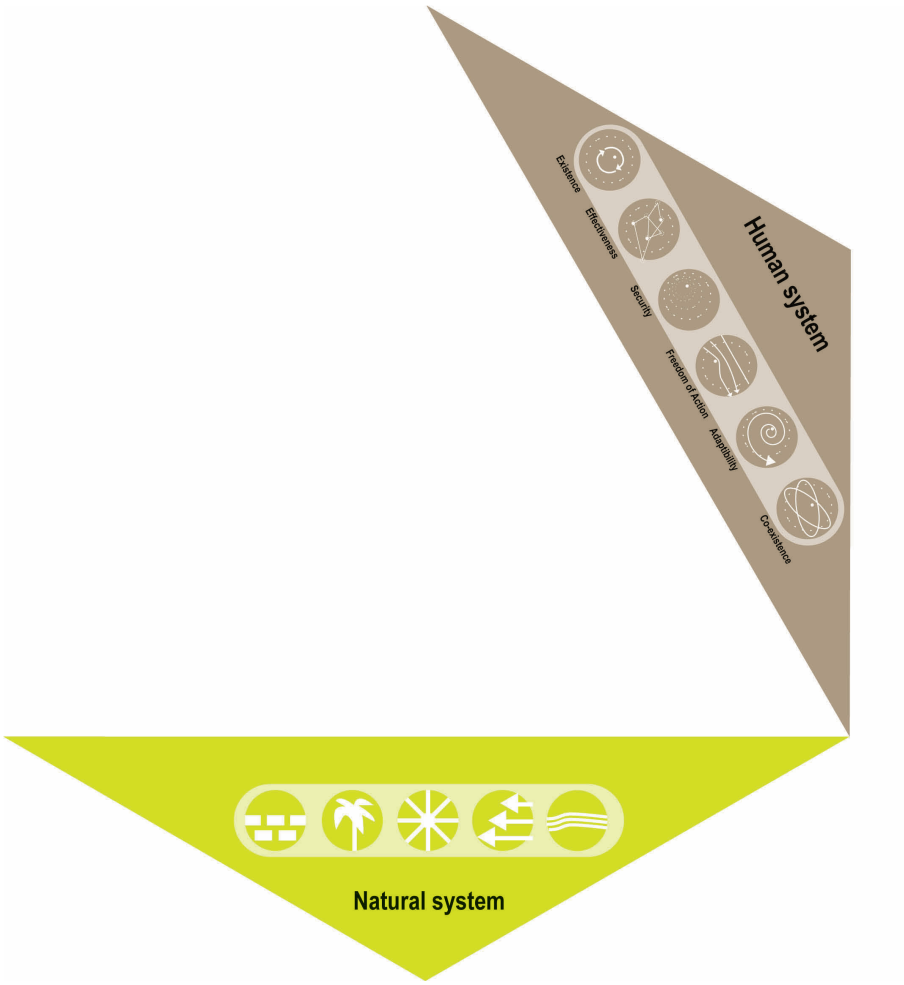


Figure 59→ Correlation axes: Anthroposhere and ecosphere

1. The human system (→0410) is determined according to hierarchies of different needs starting from the basic existence up to adaptability and co-existence in communities. Furthermore, the system of the anthroposphere follows inherent principles in an ecological system. To provide it with compensation according to its needs (that are made manifest among others in urbanism and architecture) the human system relies on the natural system (→0420), of which it forms apart. (See Figure 59)

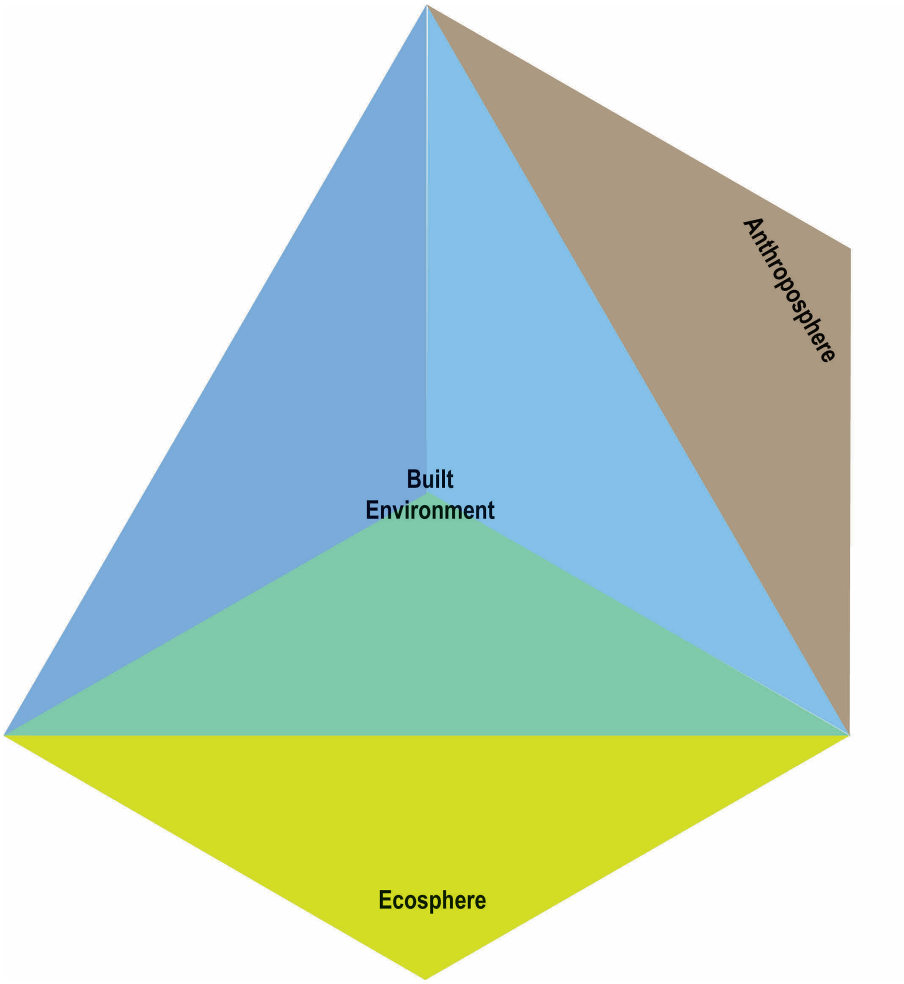


Figure 60→ Correlation axes: Anthroposhere, ecosphere and built environment

2. The built environment comprises a support system between the anthroposphere and ecosphere. Other support systems could include governance, economy and society.
System principle: COLLABORATION
The built environment establishes product and platform of human conditioning through cooperation with natural systems. The properties of human systems determine the functions of the built environment whilst collaborating with natural resources. (See Figure 61)
→→→ The human environment is the overall entity on which the composition of functions, and therewith the conditioning of the built environment, depends. The anthroposphere determines the conditioning of the environment and hence needs to collaborate with system inherent principles.

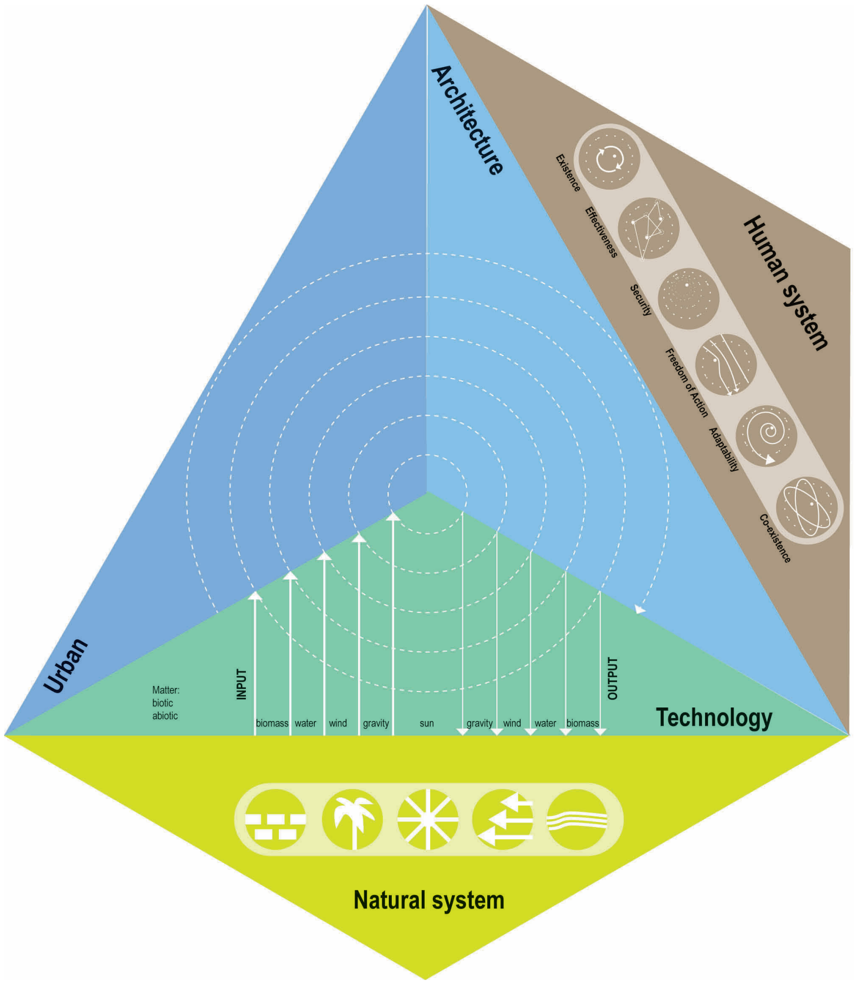


Figure 61→ Correlation axes: Ecophere input/output cycles as resources for the built environment

3. As a support system for human needs, architecture and urban structures of the built environment depend on natural resources. Resource input to the built environment of flows (water, (solar-) energy, wind, biomass) and matter (biotic and abiotic) resume in outputs. In order to comply with ecological principles, wastes or outputs need to be again cycled into the system as a resource. Through technologies (passive and active), the resources are transformed either as material or as energy, both at the input and the output stage of the urban metabolism.
System principle: CYCLING
All flows of the natural system need to be considered as cycles that are enabled through urban and architectural elements adhering to the needs of the human system. Elements of the built environment need to be directly or indirectly (via transformation technologies) connected to the natural environment and the available resources thereof. (See Figure 61)
→→→ As established in Chapter 0400, the different scales of the built environment all depend on the throughput of the natural resources that have been determined as sun, water, air/wind, biotic matter and abiotic matter. They create the cycling flow throughputs in the

built environment. The less that is lost in terms of the flows through urban and architectural levels, the more complete are the cycles. In the best case this means: output equals input, or waste equals resource.

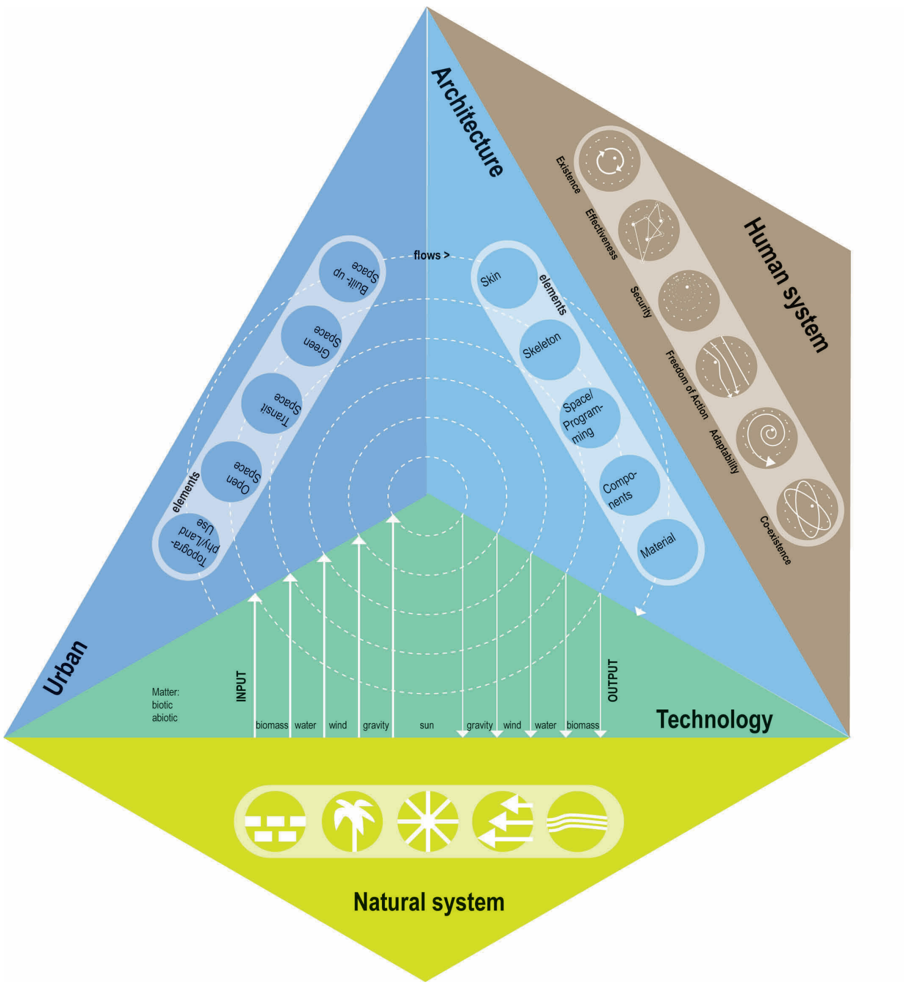


Figure 62→ Correlation axes: Ecosphere energy flows through urban and architectural elements

4. Apart from technologies to transform matter and energy to reach the urban environment as input, static elements shape and form cities and architectures. Those are implemented here as urban and architectural elements. Those elements can either enable flow throughput or obstruct it. (See Figure 62)
System principle: ENERGY FLOWS
Process drives the structure of the built environment rather than structure steering flow.
→→→ The correlation model tries to leave the elements of the built environment flexible and not fixed on a hierarchical structure. They are positioned according to spatial scales but not in order to proximities. Flows of energies and matter are the only fixed components on the proposed matrix. All other components can be structured in a way, which benefits the flow

throughput adhering to the principles of passive throughout rather than a high energy demanding transformation process.

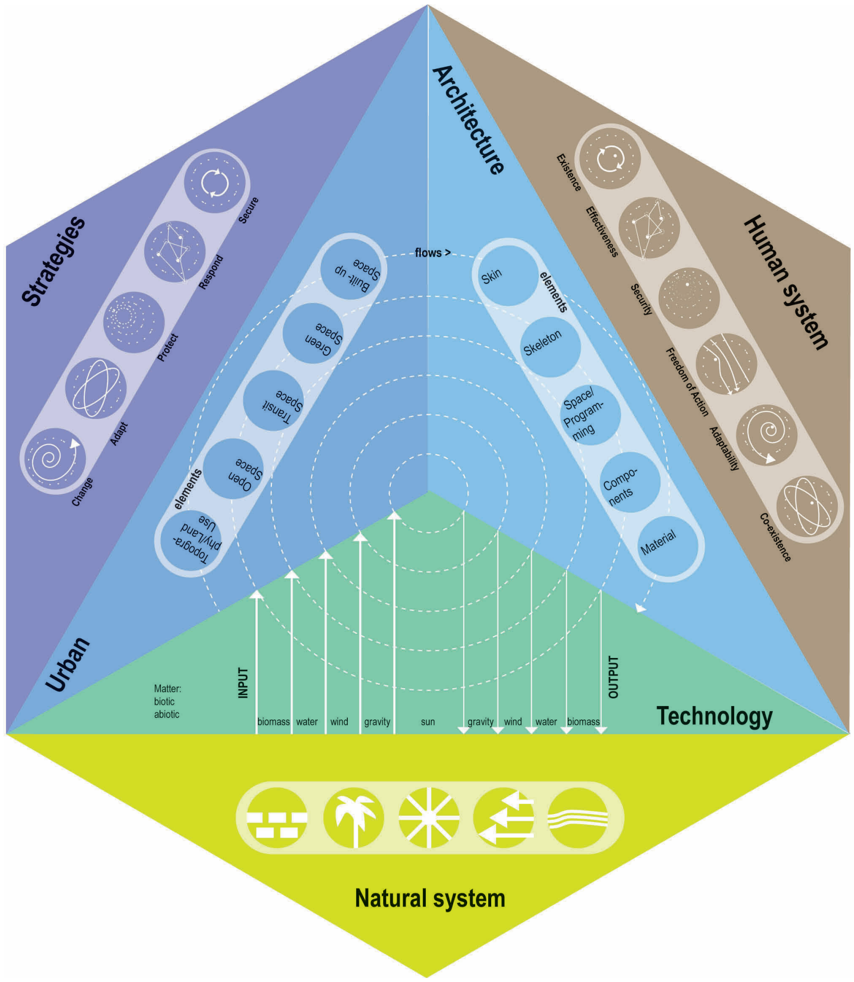


Figure 63→ Correlation axes: Strategy axis for diverse interconnection of natural, human and built environment

5. The ecological quality of the network of elements and flows, resulting in urban and architectural structures, depend on the interconnectedness of all instances: from the built environment to the human and natural environment. As a result, ecosystem inherent strategies that give concepts to link elements and flows comprise the last axes (Figure 63).
   System Principle: DIVERSITY
   The stability of an ecosystem depends on degree of complexity of its network of relationships. The more diverse the interconnections between the elements get, the more stable and robust the built environment as a system gets towards external changes.
   →→→ For the diversity of interconnections, the last axis of the correlation model offers strategies on how to connect the built environment to the natural system. Those strategies are ranked according to their abilities to diversify connections. The more complex the strategy gets, the higher is the diversity of interconnections.

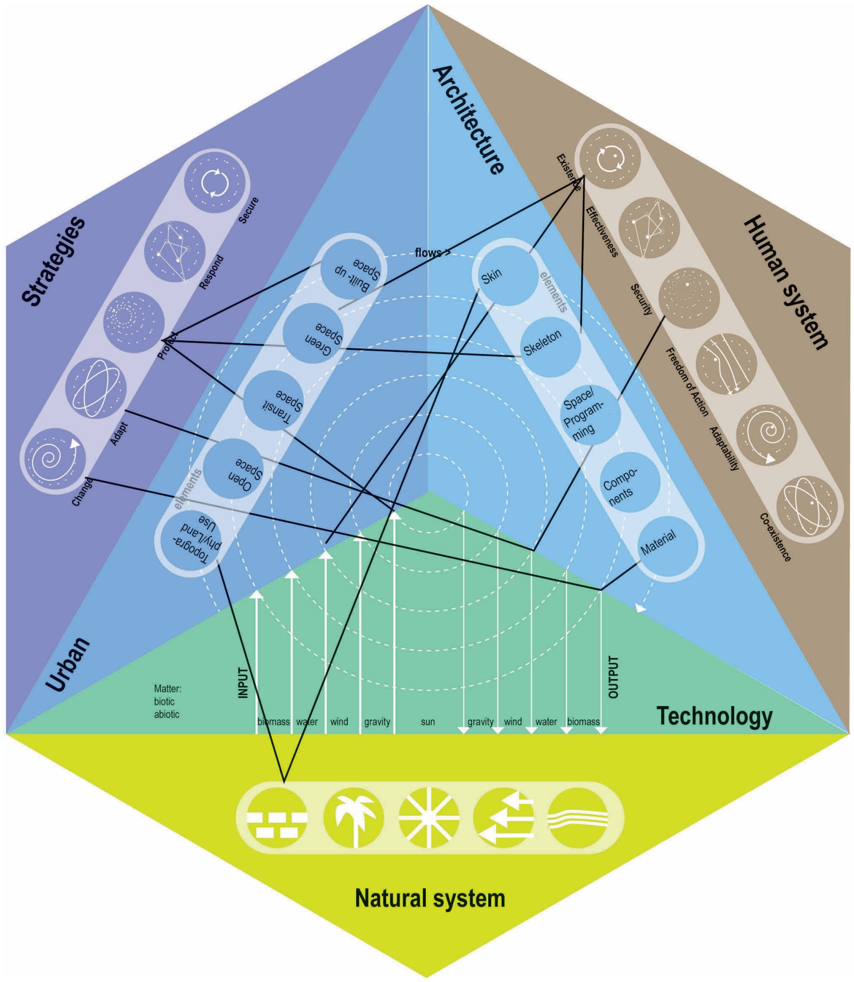


Figure 64→ Correlation axes: Interdependent correlation example

6. System Principle: INTERDEPENDENCE

The success of a whole system depends on each element of the built environment that needs to be connected to the bigger network of other elements. (Connection example in Figure 64)

→→→ Every component of the built environment not only depends on other elements in the different scales of urbanism and architecture but also inter-depends on components of the human and natural systems. Multiple co-relationships are possible. The higher the web of connections of dependencies is, the more complex the built system gets and hence the more viable it can be. Isolated components are subject to exclusion of the overall system and are therefore not viable for an ecologically responsive development in the long run.

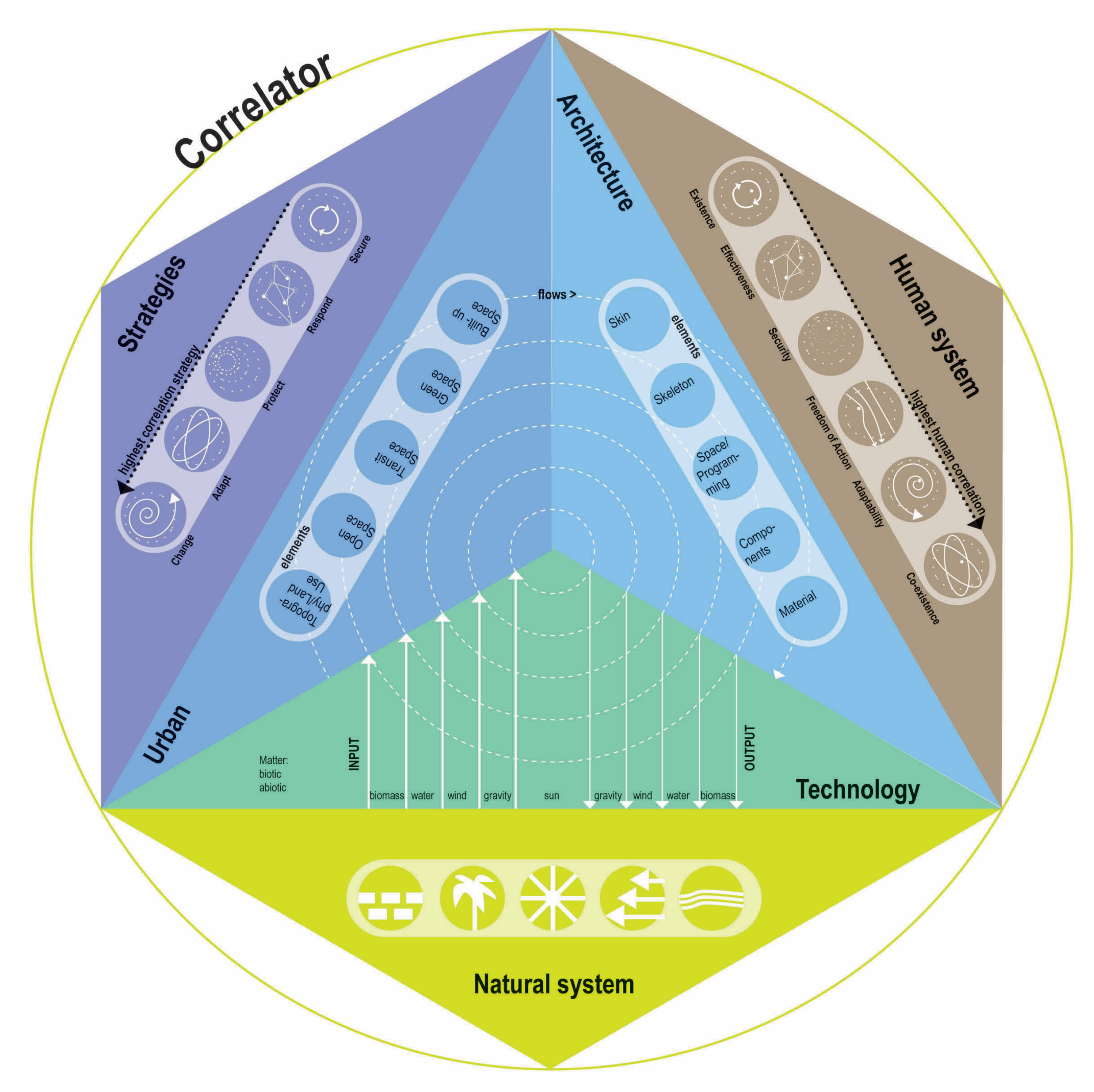


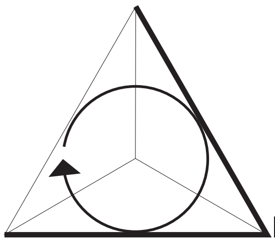
Figure 65→ Correlation axes

7. System Principle: FLEXIBILITY

The survival of systems is conditional on the interdependent fluctuations of their variables. →→→ Elements of the urban and architectural system are not bound to a specific structure. They are flexible and offer the possibility of being interconnected to the system perimeters of the natural and human systems (See Figure 65). These again depend on other sub-support systems like the governmental, economic and cultural systems.

Correlator properties:

Upon forming objectives regarding ecological principles and strategies, the following attributes and characteristics of the correlation matrix (Table 9) are shown below.



Input= Output: Cycling of flows

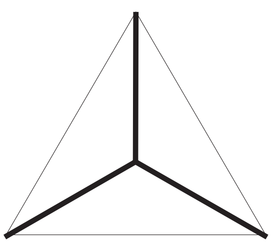
	eco-sphere		built environment compensation		built envi-ronment com-pensation		built envi-ronment com-pensation
	→0420		→0433		→0431		→0432
	nature	trans-former	technology	planner	urban	architect	architecture
flow	sun	energy	solarcollectors, heat-pumps,	flows→	orientation/shade	flows→	orientation/shade
			solarcells, PV	sun	lighting	sun	lighting
	wind		wind generators	wind	cooling	wind	cooling
			wave-powerplants		ventilation		ventilation
	water		water-powerplants	water	potable water	water	potable water
					waste water		waste water
	gravity		energy storage		storm water		storm water
	biotic		heat-and power-plants, bio-fuels		waste solid		waste solid
mat-ter	biotic	matter	material	matter	goods	matter	goods
	abiotic		material		transport		access/circulation
					communication		communication

Table 9 → Correlator matrix flows

All structures in all scales (from regional to urban to architectural to product) depend on the available resources. Those resources draw directly from the inherent natural systems.

Those different scales of the built environment need, in most of the cases, if not directly linked to the natural resources as shown in the Oasis Model (→0510), transformation into energy or material or fuels. The matrix here does not consider non-renewable fossil fuels as a resource, due to its limited ecological approach (see further discussions in →0100 and →0530). Available biotic or abiotic matter is further transformed into materials (goods, food). Other naturally occurring elements like water, wind/air and, most of all, solar energy need to be converted into units of consumption in order to be fed into the grid of the built environment. This can be achieved via active transformer technologies (see →0433 for further re-newable transformation processes) or passively (and therewith less energy consuming) as fed directly into the urban and architectural structure

(e.g. water cycle, matter and waste cycle, wind for ventilation, sun for illumination or shading strategies against.).
On the urban scale (it could also be a regional scale or a global scale), transformed or directly used resources are converted into the respective elements required to establish the comfort and condition skin that surround the socio-cultural needs of mankind. The next up-drawn axis zooms one layer down into the single urban element the built space of architecture where the same flows of resources are required.
As learned from the oasis model and also from the establishment of principles in system theories, flows though the different scales need to be reconnected into the cycle of natural resources after passing through the technological, urban and architectural scale in order to close them. Our resources are limited to that pool of natural resources only, despite the growing demands of urbanisation. Hence, smart solutions for co-cycling, multiple uses etc. have to be found through proximities of flow, function and elements. Accordingly, another property of the matrix enables Connectivity: Design elements of the urban and architectural scale have proven, in the case of an oasis system, to be closely connected to the resources flows. Shapes, materiality and spaces react directly to prevalent conditions and have multiple functions, which the built environment can cover through smart implementation of design. Reactivity of shape and design follows the flows of available resources and the functions determine the human environment.

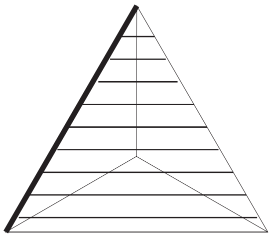


Scaling = Micro and macro, same flows and principles:

	built environment compensation		built environment compensation	
	→0431		→0432	
planner	urban	architect	architecture	details
elements→	topography/ land use	elements→	skin	facade
	green space			insulation
	transit space		skeleton	walls
	open spaces			roofs
	built up spaces			slabs
				foundation
			space	zoning
			components	opening
				windows
				doors
			material	materials

Table 10→ Correlator matrix urban and architectural elements

The distribution of urban and elements are arranged in zoom factors from materials forming building components that enable zoning spaces up to urban open spaces or the land use. Those entire zoom factors directly and indirectly depend on each other as elements and are also subject to the same flows as enabled through the natural system. (→Table 10)

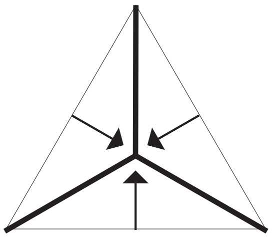


Correlating strategies according to complexity level:

	Correlation strategies
	→0330
Complexities	concepts
secure	reduce
respond	reuse
	recycle
	conserve
	mimic
	flexibility
	resilience
protect	preserve
	efficiency
	cultivate
	self-sufficient
adapt	integrate
	adapt
	self-regulation
	co-existence
change	manipulate
	self-renewing
	co-evolution

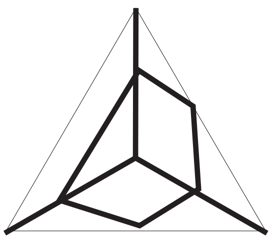
Table 11→ Correlator matrix strategy levels

The proposed concept, which is to connect all other axes with each other, cuts out already the option of static and primitive system structures, but concentrates on metabolic, self-sustaining and self-organising system principles (→0330). So, all strategies contribute to enhancing static systems into more interconnected systems, which depend on the complexity level. Obviously, the goal would be to reach an integrative adaptable urban system or even, on the highest correlation levels, a self-renewing system.



Multi-dimensional interrelations:

The shape of the matrix is non-directional and non-hierarchical in the layout of its components. Thus, it serves to enhance the point of entry to correlate different elements, flows, and approaches with each other.

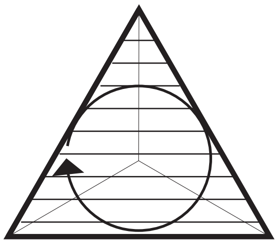


Complexity levels:

	Anthropo-sphere
	→0410
Human system	indicators
existence	birth rates
	health
	energy
	food
effectiveness	employment
	income
	transport
	waste manage-ment
	local economy
freedom of action	education
	religion
	cultural heritage
security	crime
	waste manage-ment
	city structure
adaptability	creativity
	non-gov organ.
	entrepreneurs
	training
	evolving profes-sions
coexist	communication
	community in-volvement

Table 12→ Correlator matrix anthroposphere levels

Like the ascending hierarchies on the strategy axis, the anthroposphere also relies on various stages of complexity. Starting with basic existence, the human system get more and more adaptable and hence viable if the other system hierarchies of effectiveness, freedom of action, security, adaptability and co-existence are adhered to in the built environment. (Table 12)

 Everything is related:

All axes can be interlinked to each other, whereas the flows and the natural resources are mapped onto the built environment axes and also device possible transformation technologies. Also, the six axes and fields can be arranged in a three-dimensional tetrahedron, where the connection of the axes is even easier. In general the following axiom is valid: The greater the number of connections, the greater the number of feedback loops and therefore the higher the chance of adaptability and ongoing co-evolution.

In summary the combination of elements of urban, architectural, technological, human and natural system flows and elements in conjunction to connectivity strategies: The Correlator. Here it is mapped two-dimensionally, but it could be equally seen as three-dimensional tetrahedron spanning four areas over six lattices (refer to Appendix IV for a foldable paper model). In the further chapter →0700 the implementation of the Correlator as 4D information mapping and modelling system is discussed.

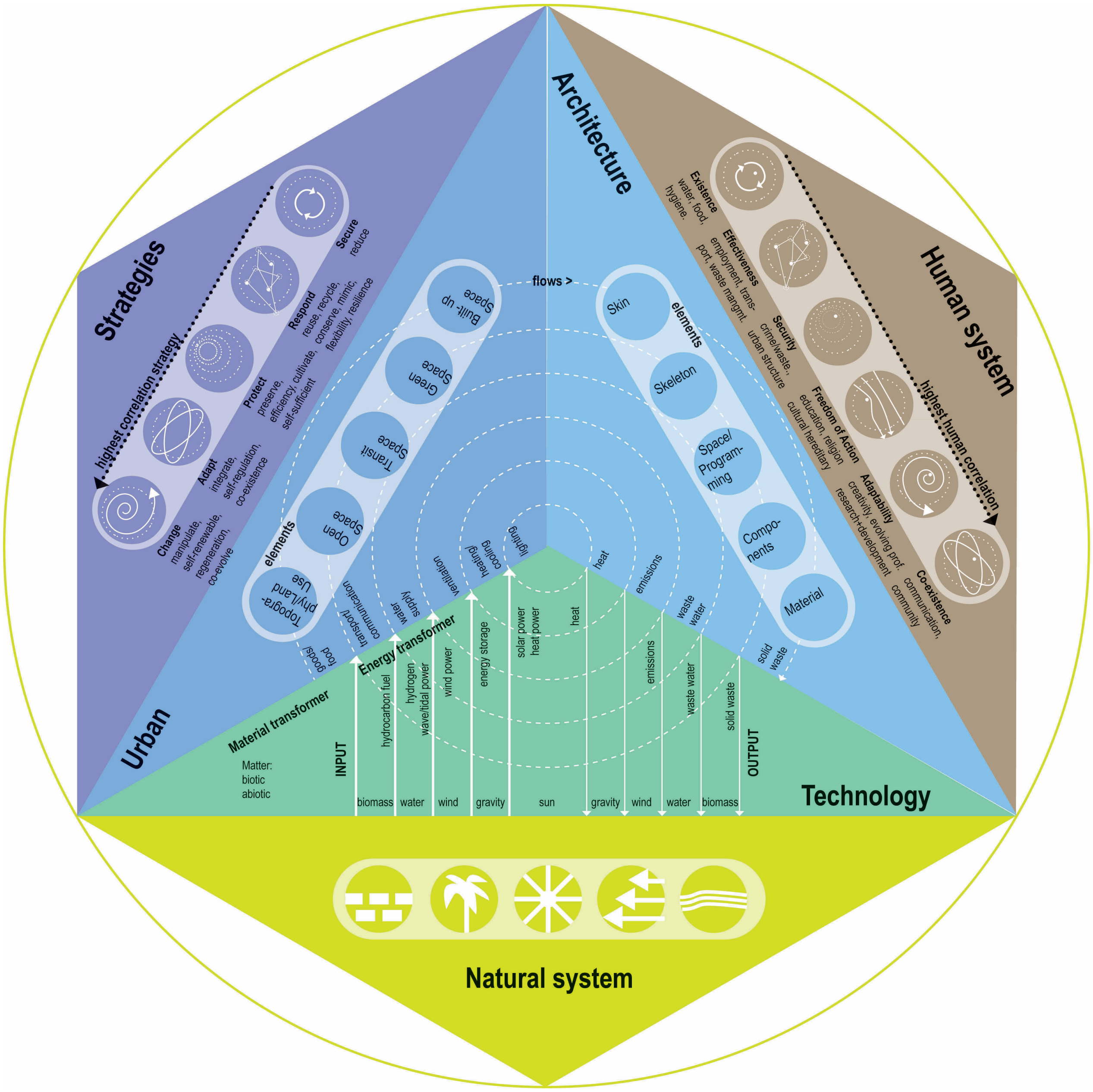


Figure 66→ Correlation Model

‘The whole is something over and above its parts, and not just the sum of them all...’ (Book H, 1045:8-10, Aristotle

0620 Discussion

> *'Our mental model of the way the world works must shift from images of a clockwork, machinelike universe that is fixed and determined, to the model of a universe that is open, dynamic, interconnected, and full of living qualities.' (Jaworski, 2006)*

As Jaworski claims, despite a shift from 'machine-like' linear to an interconnected thinking, the questions remain: How do urbanists and architects start to give recipes for solutions for a more 'sustainable' built environment and when does it become a doctrinal system that juxtaposes 'living qualities'?

An aide-memoire

Referring back to chapter →0130, it has been identified where doctrines of 'green building' rating systems in the Gulf region as imported tools of quantitative measurements follow the trend of non-connected paradigms. They do not adhere firstly to the harsh climate zone of a hot arid desert and secondly to the socio-cultural ideology. To explain this in terms of systems language, those system boundaries are prerequisites that need to be not only considered for the making of cities but also understood as prevailing conditions that shape a built environment. The Correlation model offers a matrix that orders elements and flows from the natural to the built environment via considering principles of human systems and strategies of ecological systems. It proposes a stencil of possible elements and strategies for interconnection. The Correlator maps out possibilities and action areas for the holistic thinking of architecture and urbanism as support system. Therefore, the matrix does not prescribe any connection lines between those identified elements in the system, but rather leaves the connections and the way in which they are going to be connected via the concepts or strategies given to the user of the Correlator.

The Correlator shall henceforth support design, planning and decision-making processes for the analysis, and/or design, and/or re-evaluation of current urban and architectural systems. It can be outlined as an aide-memoire for all instances of connection possibilities for the urban and architectural decision process.

Expanding the horizon

The Correlator is not a rating or measuring tool for quantities. It prompts to expand the perception of planners, designers and decision-makers from their specialist standpoint to include an under-

standing of different interrelated perspective, which helps to achieve a higher interconnectivity of all parts/elements, and flows on an urban scale and architectural scale.
The technological level is used here as a transformation device to feed natural resources in terms of energy and materials into the structures of cities. Those flows are considered to reach from a high scale design-making process on a regional scale, via an urban scale, into the architectural scale. Flows of resources stay the same in all levels and scales of the built structure, which underlines the scalability of connection principles. The question arises as to how now the elements of urban components and architectural components are linked on the one hand side to available resources streams (i.e. matter, energy and information) and, on the other hand, relate to the needs/functions of the anthroposphere.
Here the identified concepts of system inherent strategies of natural system orders (→0300) create the ways / opportunities to find synergetic solutions for a higher integrative, adaptable and thus viable city of the future.

Strategic decision-making

In an almost game-like setting, the planner, designer or decision-maker can start relating elements and flows with each other and might find concepts of integration that were not thinkable beforehand.
So far this *Bezugssystem* cannot measure the quantities and qualities like a rating system and hence judge on the 'better' or 'worse' condition of urban planning or architecture.
It does not prescribe the connections as it has been done, for instance, in cybernetics theories through feed-back loops that would then result into Gordon Pask's (see →0310) machines or sense organs.
The use of this open-network instrument is a mere reminder of combination possibilities and, so far, has not been further developed into a program of networks that become easily usable. Therefore, the final chapter will raise the question of how the foundation of elements, flows and strategies can be converted into a user-friendly application.

The limitations

The Correlator does not measure quantities and recommend necessary technologies to solve a specific problem. It rather gives an overview of what elements of architecture and the city are connected to which resources and leaves room for broad interpretation and thus hopefully also the creative use of it.
Six axes can be all correlated with all their elements, sub-elements and other aspects. As the goal of this work is to establish an overview and knowledge of those axes, it lacks a breakdown of these into ready-made recipes to explain the 'right' way of urbanism and architecture in the Middle East.

Hence, the author would like to emphasise that the latter, especially the areas of the human-made built environment, are transferable to other ‘instances’ or structures that determine our lives. Other implementations could be thought of. This would include, for instance, using the reference system with other supporting systems other than architecture and urban structure, like government, economy or education. In general, those levels of (infra) structures will always be tied to the anthropological system, follow the quest for natural resources to establishing those structures, and, if an ecologically integer development is envisaged, depend on system principles.

Strategic application of the Correlator:

> *The architecture of hybridization, the fluent merging of constituent parts into an endlessly variable whole, amounts to the organisation of continuous difference, resulting in structures that are scale-less, subject to evolution, expansion, inversion and other contortions and manipulations. Free to assume different identities, architecture becomes endless.*
> *(Berkel, B., & Bos, C., 1999)*

Certain strategies like lowering Co2 output through cutting back in energy use, reducing water supply, cycling back waste to water and energy, are currently inherent recipes of creating 'sustainable' cities, but the author claims that there are more interconnections that could be utilized to expand a strategic portfolio of solutions.

In total, the Correlator (so far) enables 3,750 strategic connections between the human, natural and built environment to be conceptualized: Five correlation strategies can be applied to the connection of five groups of natural resources into the technological transformation layer, and, from there, they are fed into five groups of urban elements and further into five groups of the architectural scale, with all of them combining to the six requirement groups of the human system environment. Since the system works as a fractal again, the elements can be broken down into sub-elements and so forth, which infinitely stretches the correlation possibilities.

Rather than breaking down possibilities, it has been chosen to give an overview of how elements and flows in a city are interconnected with human natural systems. This understanding is the prerequisite for planners, designers and decision-makers to find the right strategy in order to secure, respond, adapt, and integrate our built environment within the outlook of creating viable and adaptable urban and architectural systems.

The relevance of the correlation model

Different to quantitative measuring tools (and their limitations within an ecological understanding see →0100), the correlating matrix identifies interdependent areas in order to establish and achieve a higher connectivity amongst them. It combines ecological principles with concepts or strategies for making urban and architectural built environments. Going beyond the current strategies of minimizing the impact on natural resources (like reduce, reuse and recycle), it is possible for new research and development fields to be diagnosed, where current active and passive technology levels are not enough to achieve higher adaptabilities. Those strategies enable concepts to shape the built environment according to the prevalent conditions of the biosphere and anthroposphere. Through considering the overall ecosphere and human environment, it expands on a holistic view of the urban system. The thinking matrix can be used in the different stages of design, construction, operation, evaluation, planning and finance from different stakeholders.

Possible Conversion of a Qualitative Correlation model into Quantitative data

As stated, this research does not aim to establish a rating system but rather a platform to qualify connections between parts. Various levels are to be considered when thinking, designing, planning and deciding on urban planning, design and architecture. Therefore it has to be further discussed how such a qualitative model can be converted into a quantitative measurable approach. The setup of precise questioning of the different elements has to be defined in a process with the specific shareholders so that the outcome is able to convert the *qualis* (from Latin ‘of what kind, of such a kind’) into *quantus* (from Latin ‘how great, how much’). Accountable parameters for elements and flows would have to be established.

Obviously this process will always contain a loss of inherent information in the system since it considers specific viewpoints and expectations.

> *"Often the most important contribution a scientist can make is to discover a new way of seeing old theories or facts." (Richard Dawkins, 1989, pp. viii, ix)*

0630 Correlation recommendations

Although the Correlator has been devised as an overall matrix for the correlation of support systems to ecological systems (human and natural), the following paragraphs shall exemplify some specific indications of accountable measures to integrate the different complexities of ecological strategies into the architectural and urban context.

0631 Future Desert Oasis as integrated systems

Thinking of cities as systems, and thus consulting on the ways of integrating environmental and anthropogenic spheres into urban processes and flows, enables instruments to generate adequate urbanism that follows the principles of higher adaptability and self-organisation patterns. Future arid hot desert cities shall be able to grow in a dynamic network. This network will materialize in the morphology of the city.

The analysis on the Correlator of desert urban systems of pre-hydrocarbon development in oases settlements (see Figure 67) and of present urbanism of hydrocarbons driven resources (see Figure 68) in Oman lead to the following prerequisites for the future making of desert urbanism:

The current elements of a city, like the built infrastructure, building typologies, open spaces, traffic networks and architectural configurations, need to be converted into a productive and self-sustaining system. This quest deals with multi-layered requisitions beyond the spatial and static requirements of current elements of the built environment. They are, in future, required to function as self-organising system to support, enhance and amplify enveloping, transporting, energy transforming, material processing and communicating whilst connecting directly to the given natural resources available in the arid hot desert of the Middle East. The conversion process of present urban elements into future self-sustainable urban systems can be achieved through introducing a higher interconnectivity between the built environment and the natural resources.

In comparison to the present and past cases, a higher interconnectivity can only be reached through engaging the structures of the built environment more with the natural resources. This should be done not only through securing and protecting resources, but most of all through renewing strategies. Therefore, the functions and processes that were previously mainly dominated by the effectiveness of the human system change now into a multi-dimensional and non-hierarchical era. Architecture and cities have to become contributing partners for resources, which means that the urban structures have to become their own producing entities of resources in order to adapt to growing demands versus naturally limited resources.

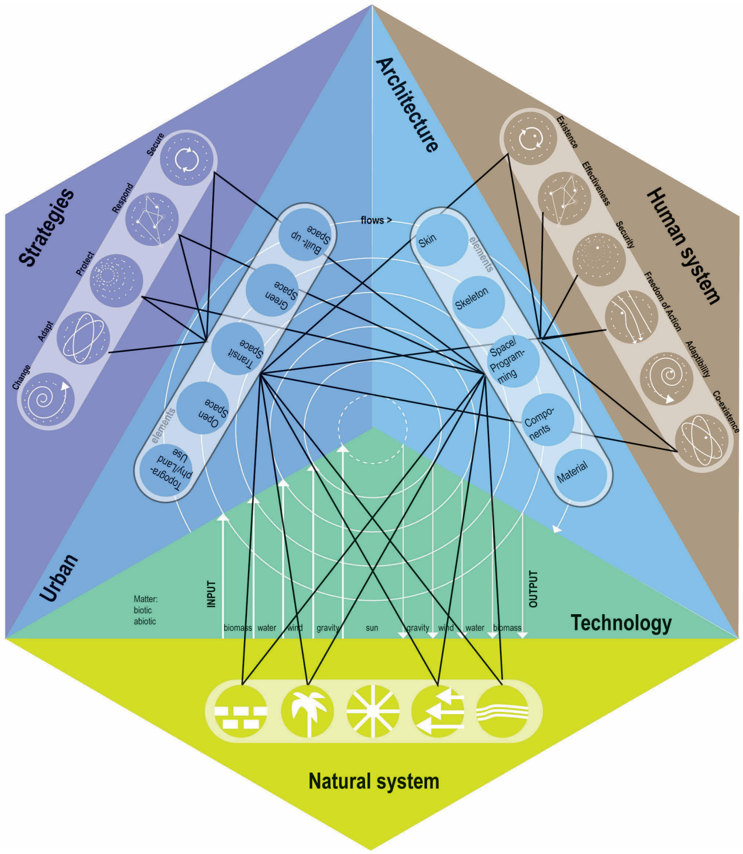


Figure 67 → Correlated past desert oasis system

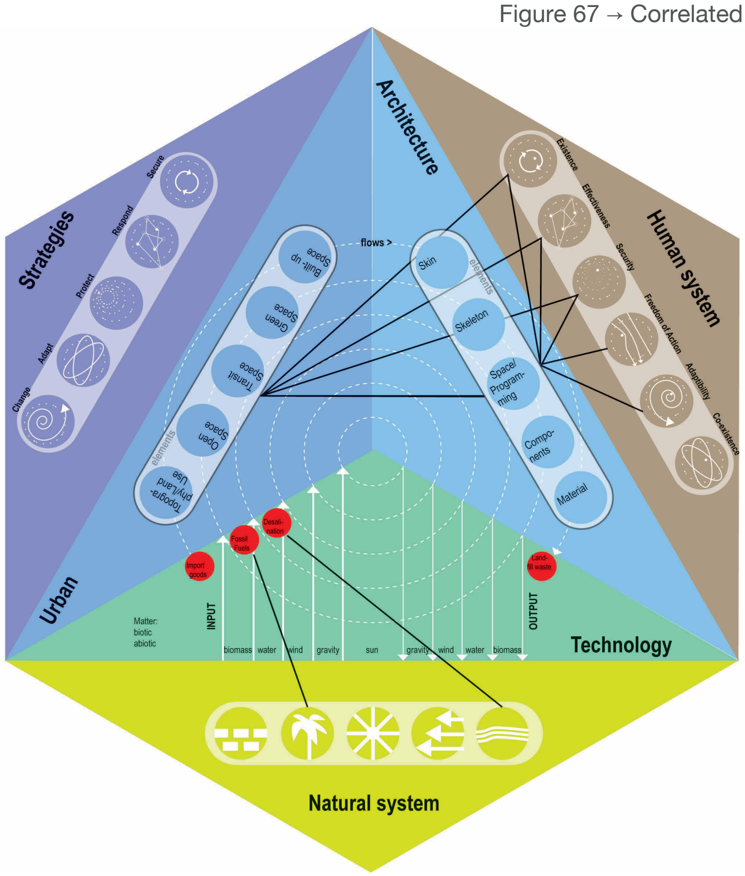


Figure 68→ Correlated present desert city system

Also visible in Figure 68→ Correlated present desert city system' is the fact that from the balanced system of the past where human needs were integrated to ecological systems and their limitations, the present urbanisation patterns mainly depend on the function of human needs and the fact that the ecosphere is, through compensating technologies (i.e. fossil powered lifestyles), entirely neglected.

In general (and this might also apply to urbanisation in other climate zones), the outlook for urban elements functioning as an ecological system is that it should be able to directly link natural resources and the requirements of the human conditioning of a city which is to achieve future desert cities that can lead to a higher adaptability, integration and efficiency through a hybrid multi-functionality of all of its components.

This attempt contradicts the metabolist movement (see →0310) of the 1960s that purely focused on design and technology as the heroes of achieving utopia to a contemporary vision with a non-form or non-design based approach of transferring ecological principles to urban processes. The Correlator vision is based on the "environment-time" of emerging global challenges for urbanism. This includes the need to shift our role as urban designers and architects to a more unpretentious envisioning of holistic processes that happen on multi-faceted layers where mirror-gazing shape and form come last and, ultimately, present new ways of thinking the city.

Consequently recommendations for future desert cities shall be approached hereinafter as one example how natural resource flows could impact the built and human environment. The Correlator as a tool makes also possible to start thinking from other axes (e.g. urban, architecture scale, strategies, etc.) or to re-develop current missing links to aim for a higher system connectivity[38].

For each resource flow following aspects are considered:

Transformer process/active and passive technology conversion process,

Impact on urban form and architecture,

Potentials for a higher correlation with the anthroposphere,

and recommended interconnection strategies.

Resulting in a combined scenario of higher symbiotic correlations in Figure 79 which is further translated into the comparable to the past and present desert urbanism correlation matrices in Figure 80→ Correlated future desert city system proposal.

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[38] Figure 68→ Correlated present desert city system: highlights that matter and waste flows are disconnected and not cycled; import products end in landfills; local resources are not utilized in the abiotic and biotic matter/product flows. This also impacts the non-local materials and components in buildings. Also solar, wind and water are not connected to energy transformation processes; Non of the living system connection strategies are applied, as well as the hierarchy level of coexisting communities is not fulfilled in the present desert city.

Abiotic resource driven correlations

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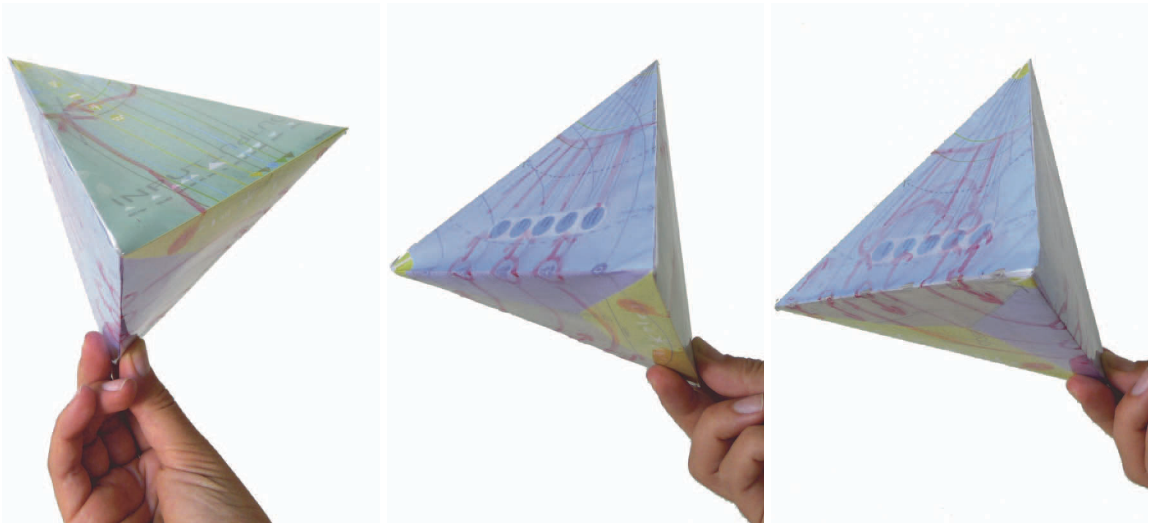

Figure 69→ Future desert oasis: Abiotic resource connection potentials marked up on the Correlator

Transformer process/active and passive technology conversion process:
Available resources like natural stone, lime, clay, loam, and other mineral compounds are raw materials to manufacture building materials like adobe bricks, lime cement, rammed earth under reduced energetic efforts. This can create local employment, training opportunities and the self-management of such products. Also taking into account that the entire life cycle (from extraction, to destruction to the reuse of the material) of such products stays within the same region. Additionally, especially lime based materials also contain the ability to capture carbon emissions and purify the air accordingly.

Impact on urban form and architecture:
The above-mentioned material potions demand for solid construction methodologies of the architecture and the compound of buildings. This could lead into compact clusters of built up space, that allows for shaded open spaces, narrow corridor-ed traffic spaces and green spaces that might include functions like solid waste cycling. Such dense urban design can offer the opportunity for the local community, to self-manage and self-regulate their quarters as decentralised units. Given the climatic aspects of desert environments the envelope design of buildings with respect to abiotic materials could create carbon capturing facades, that provide thermal mass for insulation and allows for compacted cells with minimal but affective openings for natural ventilation and lighting.

Potentials for a higher correlation with the anthroposphere: To emphasize on the possible diversification of local and regional industries, local resource conversion industries not only add to local employment, development of training (especially for such age-young nations) but also establish unique identification factors for the community and individual expertise that distinguish certain regions from each other. This also has the potential to interconnect with other similar practises at similar cultural, resource and climatic prerequisites of the site environment.

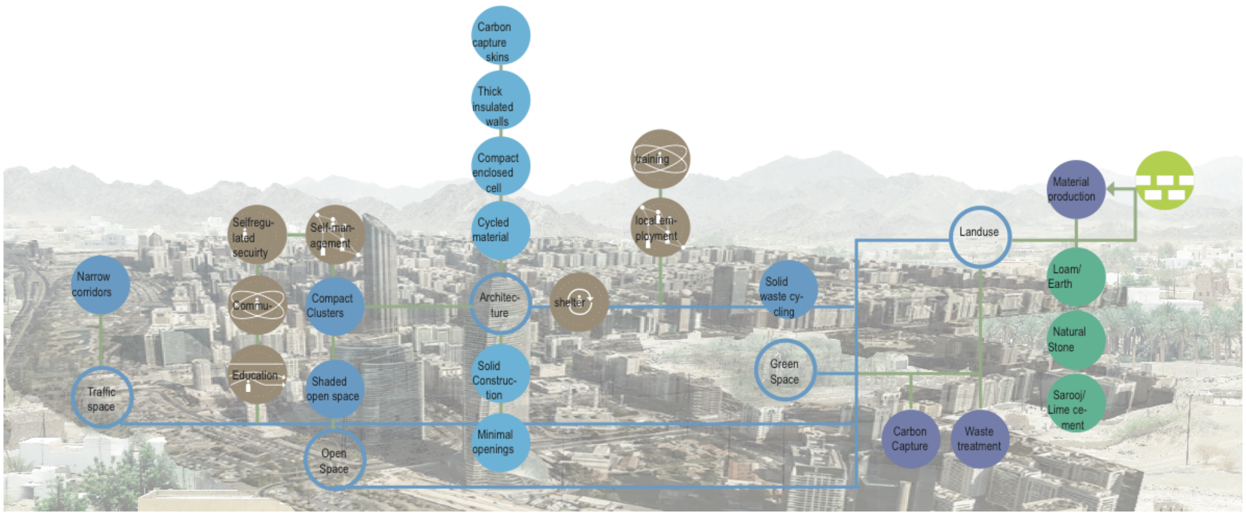

Figure 70→ Future desert oasis: Abiotic resource driven urban correlation potentials

Strategies recommended:

Adapt building technologies to abundant local resources, use and reuse those effectively, and therewith conserve land inherent qualities that have a multiple benefit (e.g. earth construction bio-climatic aspects, re-use aspect and then carbon capture aspect). Therewith reduce non-system immanent[39] materials.

Cultivate pre-fossil fuel/traditional local knowledge of constructing materials and techniques in order to develop them further via research, education and entrepreneurialism.

Cycle matter under energy efficient means that incorporates a whole life span (from cradle to destruction to production) evaluation.

Integrate and synergise with all other resource flows and cycles.

[39] Depending on the urban system boundaries that define the radius of 'locally' sourced matter.

Biotic resource driven correlations

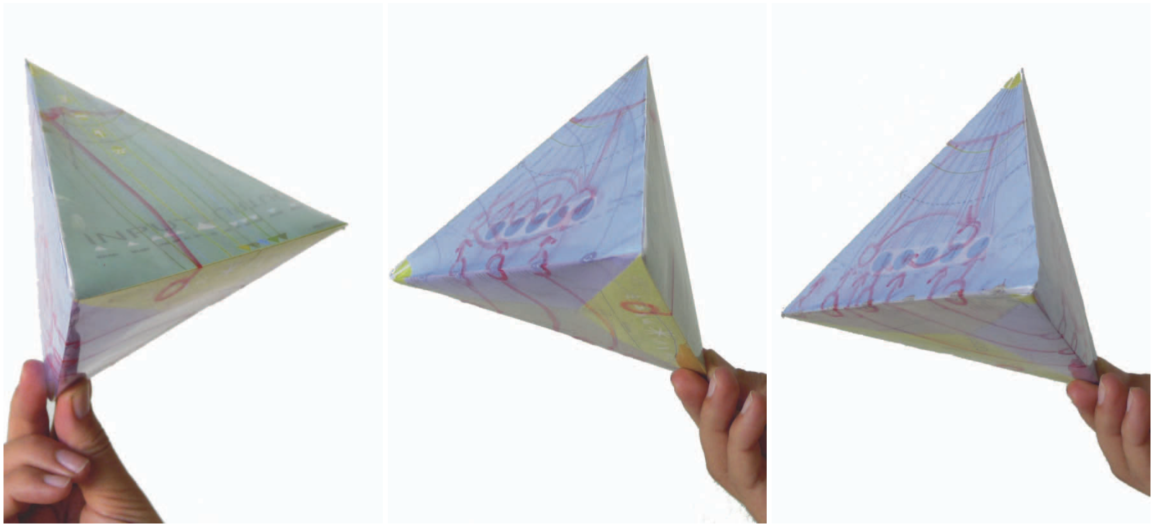

Figure 71→ Future desert oasis: Biotic resource connection potentials marked up on the Correlator

Transformer process/active and passive technology conversion process:
Regionally sourced biotic matter has the potential to provide biomass for nutrients, fuel and construction materials. Not just plant fibres, timber or animal hair, but also living organisms (bacteria, fungi and plants) can be utilised for the built environment in an integrated, low energy conversion approach. Especially in low biodiversity
and water scarce climate zones like the desert only climate-adaptable species should be considered for a possible conversion process.

Impact on urban form and architecture:
Potential areas of biomass utilisation applied basically to all urban and architectural surfaces that could receive enough solar, water/humidity and nutrient input. Here the landuse of several functions of spaces, roofs but also facades could be thought over. On a macro scale well planned green corridors or zones could lead to the adequate ventilation values to micro cooling effects of entire clusters. In harsh climate zones like arid and semiarid desert environments highly sensitive green scapes should not be used for beautification, but only if further benefits are enabled for food, materials, thermal compensation of building envelopes, healthier environment and recreation values for inhabitants.

Potentials for a higher correlation with the anthroposphere:
The application of organic materials may provide resilient and low energy demanding construction materials that not only could become a 'living skin' of buildings that could produce nutrients, convert carbon dioxide and at the same time provide micro-climatic cooling and insulation buffer zones for the internal building mass. This possibility of vertically applied urban farming demand locally

adapted knowledge, research and training which could enhance local employment opportunities adding to local industries as well as a gradual evolution of tailor made professions.
To emphasize on local and regional industries that can be diversified, local resource conversion industries not only add to local employment, development of training (especially for such age-young nations) but also to establish unique and individual expertise that distinguishes certain regions from each other. This also has the potential to interconnect with other similar practises at similar cultural, resource and climatic prerequisites of site.

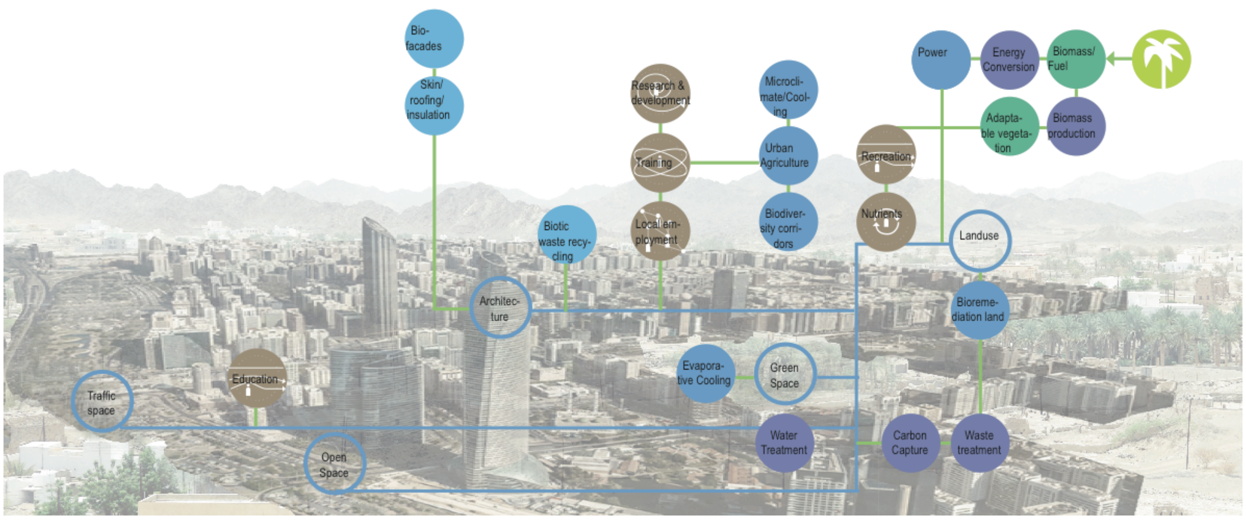

Figure 72→ Future desert oasis: Biotic resource driven urban correlation potentials

Strategies recommended:

Respond to given bio-climatic conditions, nutrient and biomass cycles.
Cultivate endemic bio-matter in order to effectively (low water, high temperature) preserve soil, land and aquifer quality.
Prioritise value of nutrient provision over bio-fuel and putting energy recovery as the last step of the biomass lifecycle (only use for recovery after extensive cascaded use).
Integrate biotic matter production wherever feasible and preserve bio-climatic endemic species over ones alien to the system for urban agriculture.
Preserve local knowledge and give incentives to develop further.
Integrate and synergise with all other resource flows and cycles.

Water resource driven correlations

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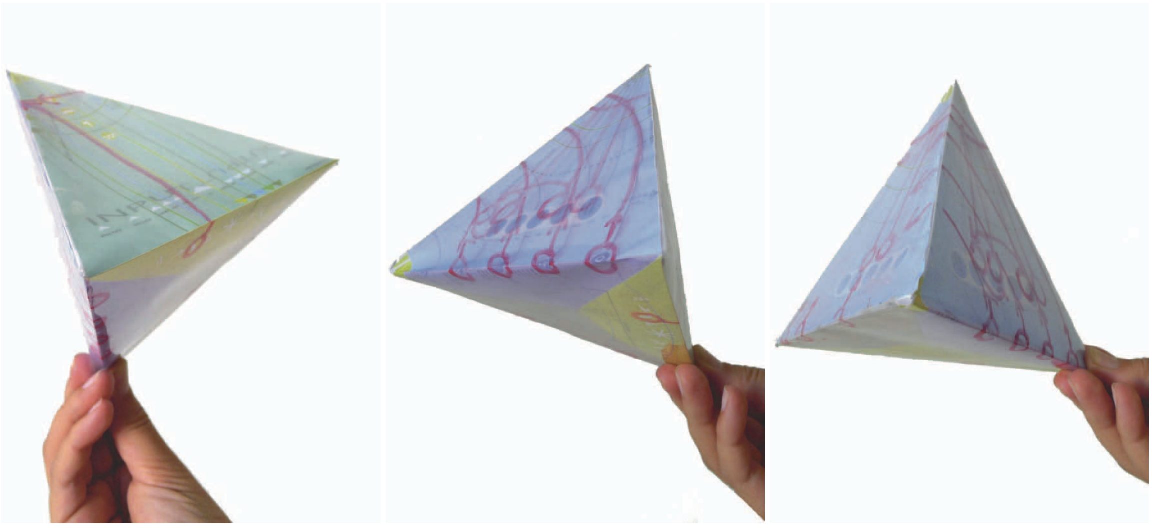

Figure 73→ Future desert oasis: Water resource connection potentials marked up on the Correlator

Transformer process/active and passive technology conversion process:
Water is the most valuable source of life in arid and semiarid eco-regions. Therefore its use and conversion process into potential energy entities needs to be carefully integrated into an overall cycle from precipitation, aquifer reservoirs, potable water for humans, animals and plants, to waste water, to nutrients and potable water again in order not to lavish the most precious ingredient of any oasis settlement. For seawater desalination processes solar thermal conversion should out-number the pressurised, high energy demanding chemical filter processes. Water according to its geographic location can contribute to generating hydropower, thermal energy, osmotic energy and due to its physical density has a reasonable thermal storage capability.

Impact on urban form and architecture:
Traditionally oasis settlements would occur where water was abundant or made available via engi-neered irrigation canals and tunnels leading to regional wells. In this respect landuse policies could be integrated into an environmental evaluation of available water resources on which the size of clustered settlements could depend. Such clustered building volumes would need to equally re-spond to carefully considered water distribution (cycled) and multi-functional. Water networks could be integrated into skeleton and façade elements to provide heat/cooling flow-throughs pow-ered by interaction of exterior and interior microclimatic differences. Combined with biomass and ventilation, such facades could become air-conditioning units themselves.
A local compound water network could then also integrate grey water irrigated smaller scale agri-culture as well as utilising open/green spaces or even facades for cascading water filtration ter-races via gravity and/or vegetation (e.g. reed beds), which again could combine functions like

waste water cycling, biomass production and micro-climate adapted communal shared space for recreation.

Potentials for a higher correlation with the anthroposphere:
The moral and canonical law constitution in Middle Eastern countries is based on the sharia, which initially includes the literal meaning of the path to water. Thus this ideology revolves around water as the life-spending element in the desert and can be emphasised on via education and awareness programmes in order to follow preservation measures (which are currently neglected, see >0522). Self-management and monitoring on local scales could contribute to communal values and their consumption patterns as well as to the local economy. Furthermore regional water and hygiene standards assessment followed by research and development of intelligent water cycling methods could be explored. Lastly water adds to the co-existence of the human system also through its recreational value.

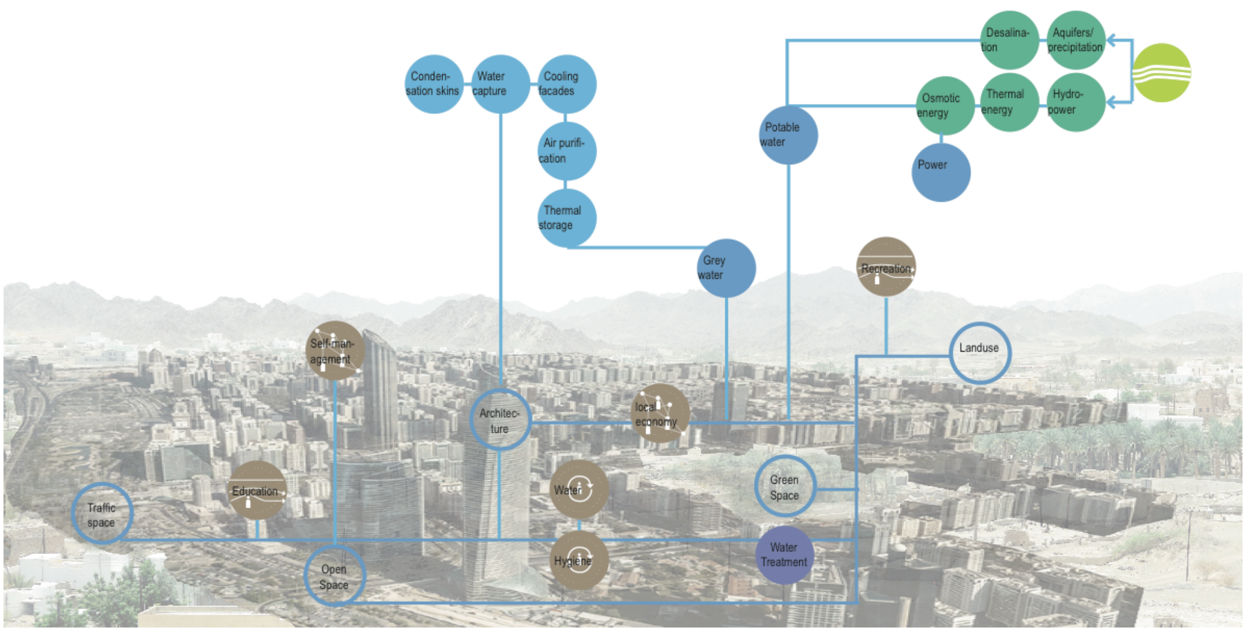

Figure 74→ Future desert oasis: Water resource driven urban correlation potentials

Strategies recommended:
Preserve local water sources. Reduce demand. Change consumption pattern of people and devices used. Self-regulate micro water (-waste) cycles within single builds, compounds, quarters, etc. Mimic natural water cycles (evaporation, precipitation cycle) in controlled micro-climatic spheres. Cultivate multiple functions for water in buildings and urban compounds e.g. as thermal carrier, thermal storage, evaporative cooling enabler, hydraulic force, biomass enabler, etc. Integrate and synergise with all other resource flows and cycles.

Wind/Air resource driven correlations

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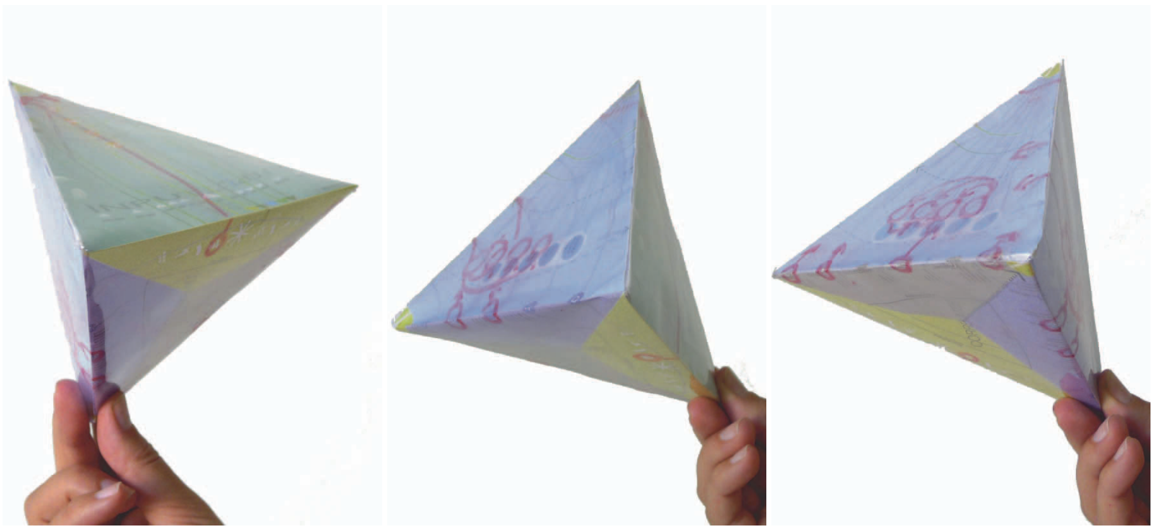


Figure 75→ Future desert oasis: Wind/Air resource connection potentials marked up on the Correlator

Transformer process/Active and passive technology conversion process:
The movement of air can utilise passive cooling and natural ventilation in the urban and architectural context depending on the design and implementation of building masses, corridors, shafts, etc. Also it can actively be converted into electric, mechanical power, etc. and contributed to micro-cooling aspects of evaporative cooling in green spaces.

Impact on urban form and architecture:
Thereby the urban shape of building volumes has a huge impact on where ventilation effects can take place and how effectively. For instance traffic and open spaces could be designed according to needed cross section of wanted ventilation drafts, or thought the other way around that ‘left over’ ventilation driven spaces could be used for circulation, etc. Accordingly buildings could be activated through linking to such ‘urban’ ventilation corridors via integrated wind towers. Dynamic wind patterns could be integrated through sensored active building and urban parts. Vertical facades/shafts of buildings could capture wind and convert it into power and additionally cool building parts. Natural ventilation of interior spaces is important to maintain healthy, hygienic and emission free environments. This has to be considered for enclosed cells, spacing and programming of buildings.

Potentials for a higher correlation of the Anthroposphere: New schemes of emission treatment and landuse in order to generate power could enable local economy opportunities also the communal management of quarter/compounds. New industries require the specific training and education in order to provide long term management and facilitation mainly in the factors of energy conversion and emission treatment. Carefully considered open space configuration that don’t react to purely car driven, but especially positively ventilated (without being too drafty) could also benefit the aspects of social coesion of co-existence according to socio-cultural aspects.

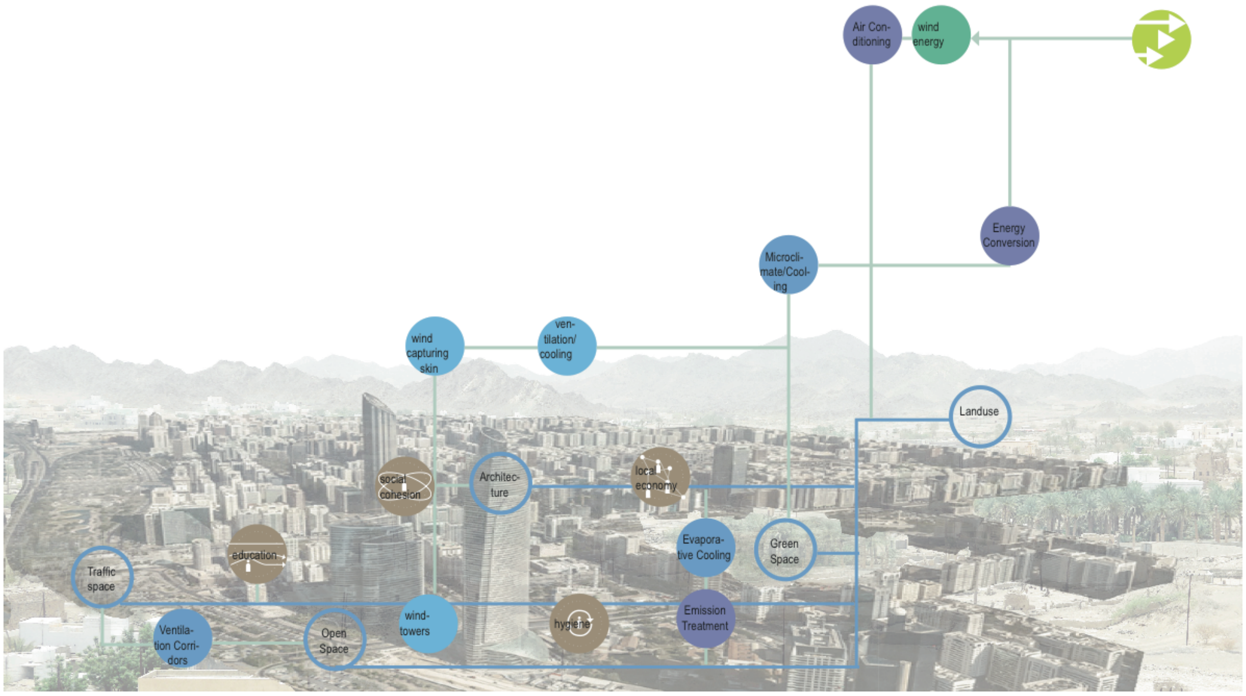


Figure 76→ Future desert oasis: Wind resource driven urban correlation potentials

Strategies recommended:

Self-regulate ventilation and passive cooling via passive urban and architectural design of voids, corridors and massing. Active efficiency use of wind energy through wind tunnels, turbines, etc. which influences landuse policies and industries.

Adapt building skeletons and cavities into wind-towers, channels and tunnels, which serves air exchange, cooling, emission treatment and contributes to overall indoor climate and overall hygienic wellbeing at the same time.

Integrate and synergise with all other resource flows and cycles.

Solar resource driven correlations

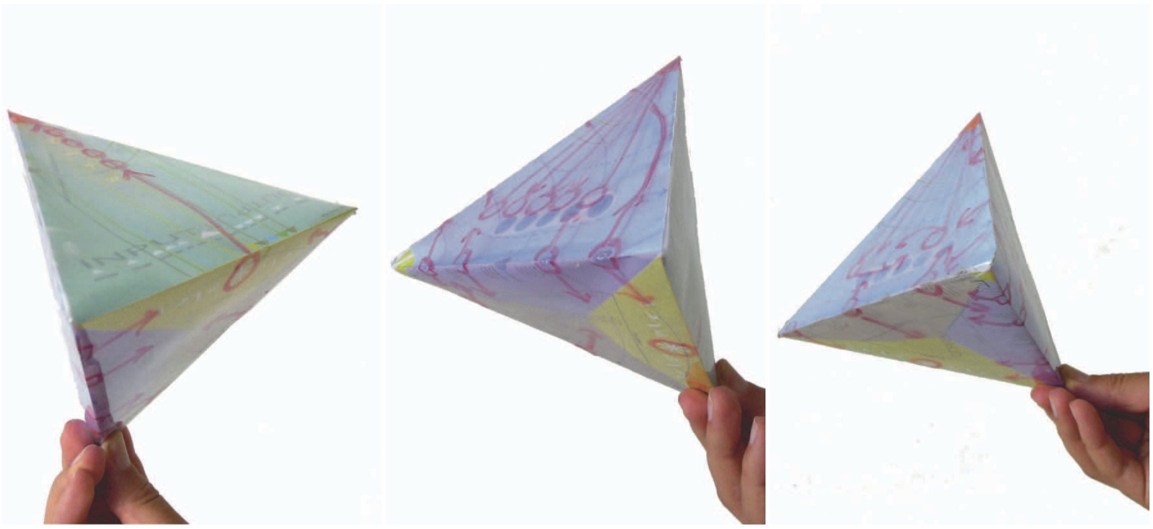


Figure 77→ Future desert oasis: Solar resource connection potentials marked up on the Correlator

Transformer process/Active and passive technology conversion process:
First of all solar input powers and drives all other resource flows especially photosynthesis and therewith biotic mass production. Second of all solar energy can be converted via solar thermal, chemical, thermo-electric and photovoltaic technologies into usable energy carriers. Other transformation processes include that solar power can transform matter into products (e.g. earth to adobe blocks, silt to glass), UV irradiation can disinfect and clean impurities (e.g. for drinking water), thermal condensation, evaporation and powers other resources (vegetation, water, wind).

Impact on urban form and architecture:
The utilisation, inclusion and adaptation of solar power into the urban context demands effective self-regulatory considerations that impact urban form and envelopes. It is thinkable to integrate solar harvest (thermal, chemical, electric energy) and energy storage (chemical, thermal, gaseous) in traffic, open and green space as well as the architecture. However the goal for solar exposure in terms of insulation and openings towards solar irradiation demand in hot and arid environment is reduction. Hence the ratio of compact clusters on the one hand and abundant solar conversion skins/envelopes on the other needs to be carefully considered. Natural daylight might be introduced via light-shelves and -tubes rather than massive openings. Thereby also the function of the façade of a building might be expanded from purely servicing interior climate, opening and appearance aspects to active and passive energy-conversation skins.

Potentials for a higher correlation of the Anthroposphere: Research and development of adequate passive design strategies and high-tech active technologies need to be included as on-going feed-back mechanism to the ever re-constituting system of a city. It also holds opportunities for entrepreneurs to contribute to the challenge of effective solar conversion and storage processes as well as the integration of education and training for the evolving industries. Not to forget as well that the existence of humans also require solar input for healthy survival.

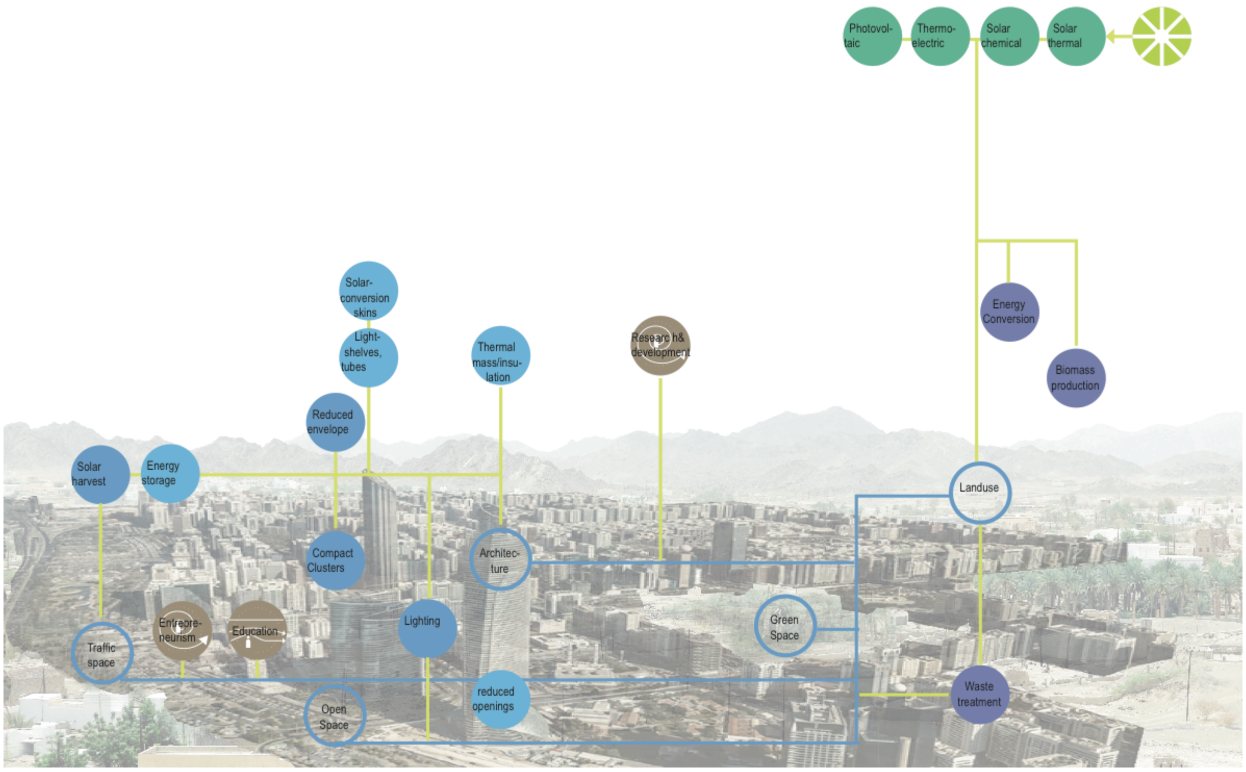


Figure 78→ Future desert oasis: Solar driven urban correlation potentials

Strategies recommended:

Reduce thermal envelopes of buildings to direct irradiations. At the same time integrate passive and active solar harvesting at any open plane possible.

Mimick photosynthesis inspired processes for energy conversion and storage questions (e.g. chemical conversion, solar power to hydrogen gas conversion) at any urban/architectural surface possible.

Respond to protruding solar impact via flexible adjustment of surfaces.

Co-evolve smart compound (nano-technological surfaces) materials that are able to convert solar power into adequate energy carrier (which might also ask for other forms like ATP as carries, rather than electricity).

Integrate and synergise with all other resource flows and cycles.

Resource driven urban correlation potentials combined

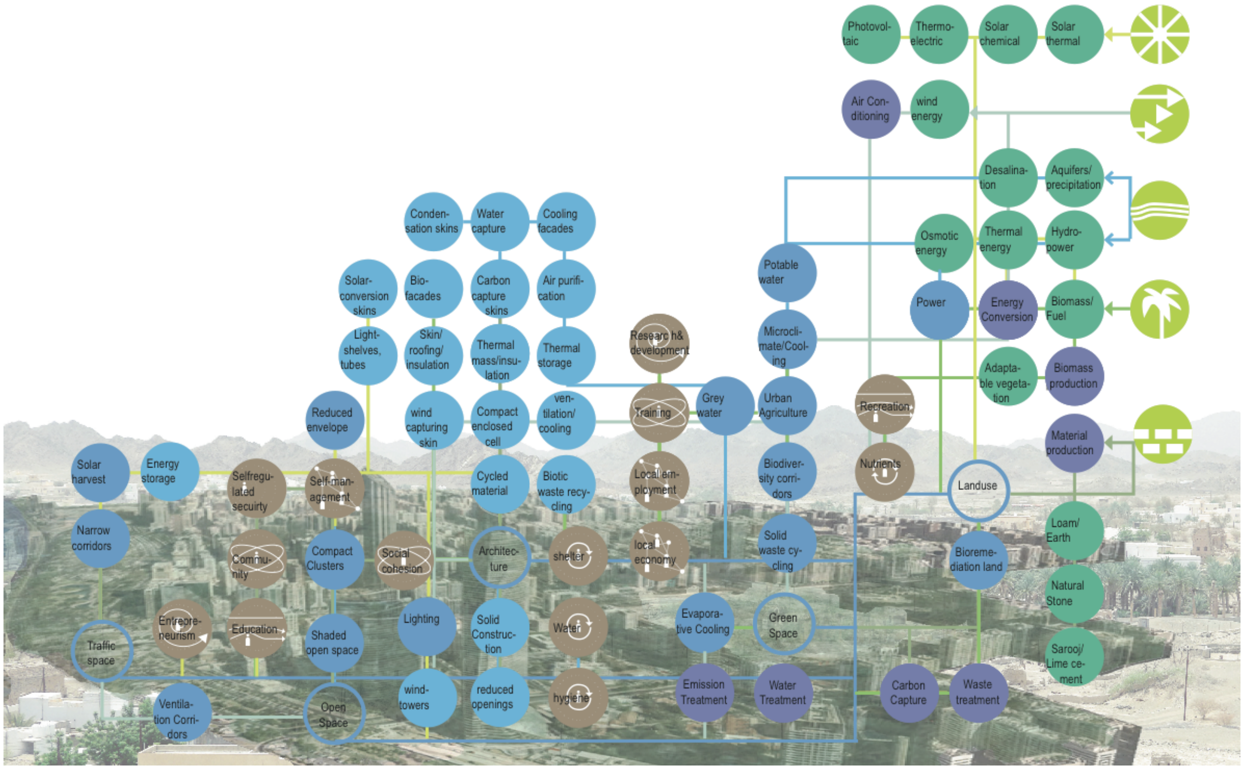


Figure 79→ Future desert oasis: Resource driven urban correlation potentials combined

An overlapping of various correlations allows for multiple synergies for the systemic throughput of natural resources (See Figure 79→ Future desert oasis: Resource driven urban correlation potentials combined). However it is not enough to just add the recommendations given per resource cycles, but to establish synergies amongst those and the built environment including anthropic system principles. The same, but less specifically detailed and more schematic depicts the correlation matrix in Figure 80. Here the strong interconnectivity between the different urban, architectural, human and natural resources levels could be achieved whilst applying various strategies of correlation. In the end the goal is it to analyse missing links of the past (see Figure 67) and current urbanism trends (see Figure 68) in order to come up with higher levels of interconnectivity between Eco-, Anthropho-, and Built Sphere as demonstrated for a potential future desert urbanism above and summarized in the correlation diagram below.
As learned from the traditional oasis settlements, it is a dialogue between the design process and (resource) flow process in a non-hierarchical interconnected relationship that shapes the structure of living environments. This could be achieved by a combination of active and passive technologies, which again support and equalise hybrid process flows. Future desert cities (but also cities in other climate zones) need to include a combination of functions of active, passive and infrastruc-

ture design strategies to fade into non-hydro-carbon depended cities. This implies the ability to grow in dynamic networks. Those networks will materialize in the morphology of the city and at the same time feed-back into the network connection's effectiveness. Here, the flexibility of space utilisation through multifunctional mixed use creates adaptability. At the same time qualities of space, dimension and characteristics need to reflect the local and regional identity, character and history in order to enable a well-balanced human system.

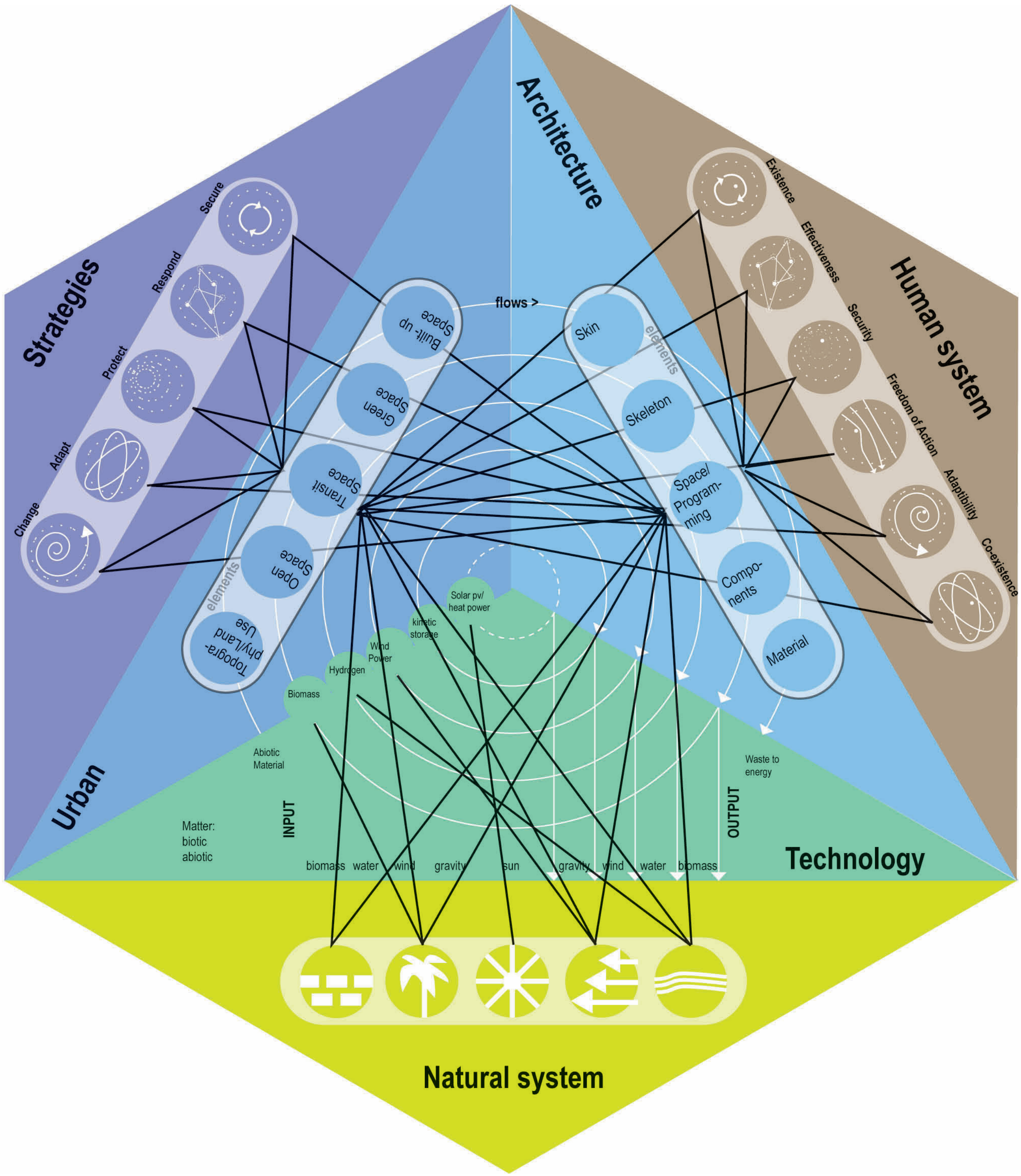


Figure 80→ Correlated future desert city system proposal

0632 Strategy complexities examplified on the urban environment

On a macro-scale level, the potential interconnections of the urban, architectural and technological transformation process levels are exemplified in the following through the discussion of the different strategy complexity levels as concepts for correlations. Thus, this indicates the relevant decision-making needed by urban planners, architects and other urban stakeholders to deal with non-hydrocarbon based resources in conjunction with an abundance of water, arid climate zones and scarce biotic resources.

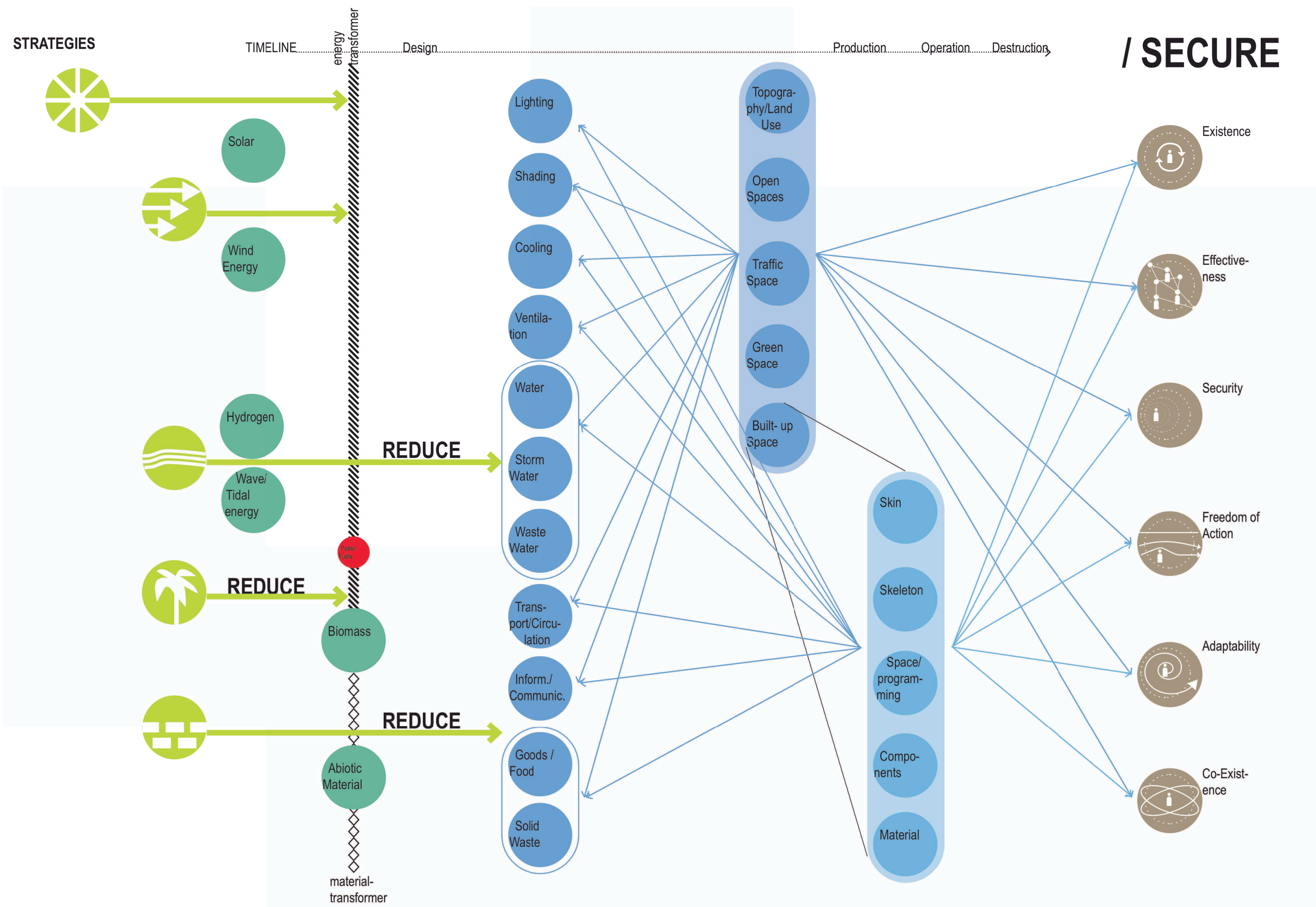


Figure 81→ Strategy complexity: Secure

Secure: Securing natural resources is currently the most emphasised strategy amongst policies referring to sustainable development approaches. The quest is to reduce all material and energy flows in order to reduce waste outputs (heat island effect, emissions, landfills etc.). The supply of water and energy into the urban system is driven by the demand of its population. Often those approaches are solved by devices (e.g. water-saving taps) that are retrofitted, whereas the urban structure and especially the consumer's behaviour stays the same. But, as shown in the correlation model (→0620), this strategy can also be applied to urban and architectural elements (e.g. open space, skin, material) and has an effect, respectively, on the design of the shape layout. For instance, this would include the desire to reduce the envelope areas of urban volumes in compact cities so as to minimise the impact of solar irradiation and provide shading, ventilation drafts and a social cohesion at the same time. Also, for the architecture, the aspect of reduction has consequences on the design. Beyond the technological solution to compensate spatial microclimate, especially passive design considerations (volume, orientation, shape, form, texture, etc.) could contribute to the reduction matter, energy and information. Reducing openings, providing (self-) shading volumes, material weight, artificial cooling through cross-ventilation or even the transport energy needed to import construction materials by using locally available products all help to reduce actively needed energy to compensate non-climate responsive design, construction and operation (as seen in →0530).

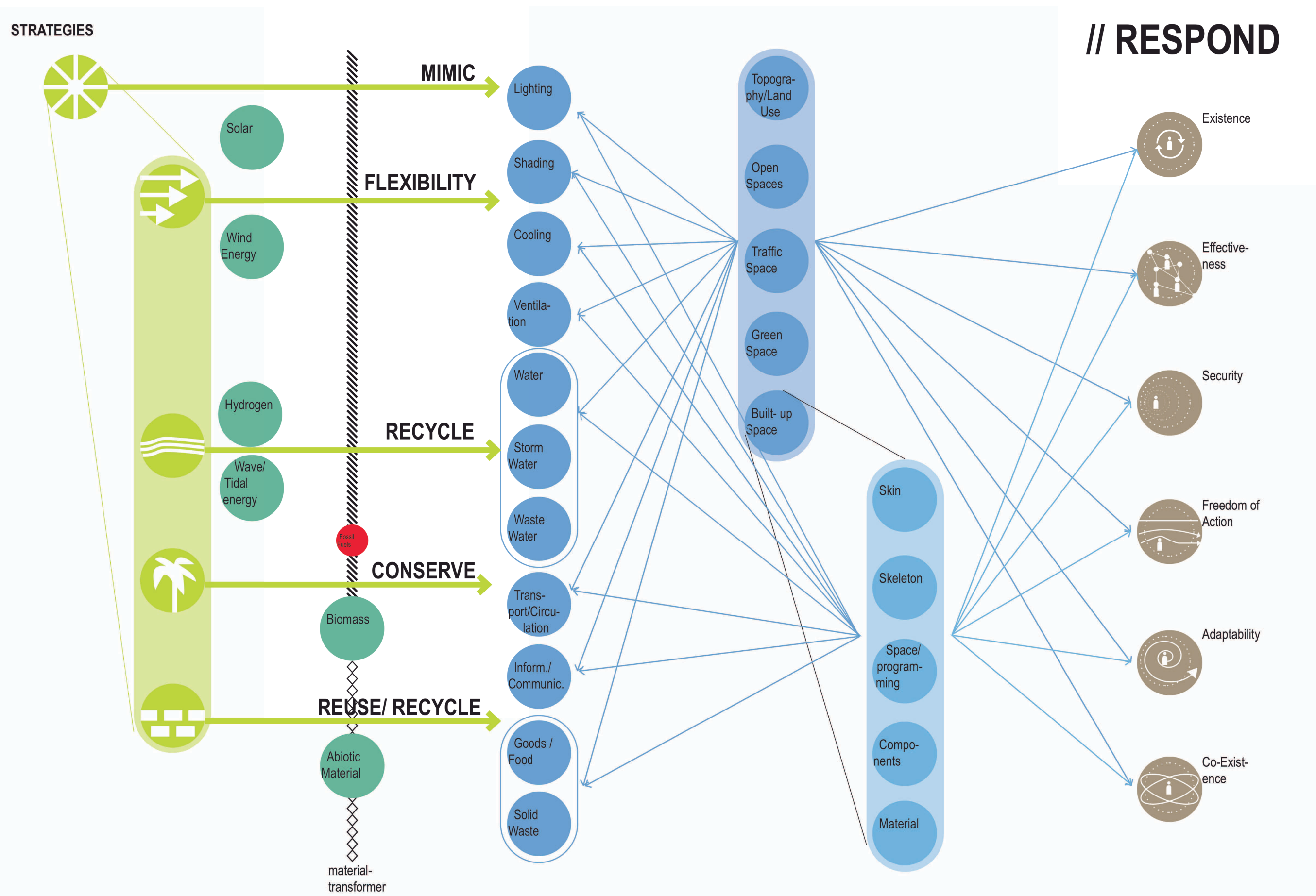


Figure 82→ Strategy complexity: Respond

Respond: The feed-back orientated strategy of 'respond' secures flows as cycles within metabolic systems. Here, also, the implementation into the urban system is mainly driven by aspects of resource transformation and flows through the urban system: Recycling water and biotic materials and wastes, reusing or recycling abiotic materials or responding to energy needs through smart sensoring and metering, are well-known principles to promote so-called 'eco/green/smart-cities'. In architecture, there is a tendency to expand this concept of responding to biological systems by mimicking processes and shapes through parametric design options (as related to cybernetics, for discussion of which see →0310) or using biotic construction materials. Also, the technological realm concentrates more and more research and developments on responding to the natural system through bio-mimetics, cradle-to cradle approaches, renewable energy sources, water recycling and harvesting, industrial symbiosis or other ecosystem services like cycling nutrients, pollination and decomposing wastes.

Apart from technologies as an application to buildings, it is also thinkable to provide architectures and urban fabrics with a higher flexibility by designing them not only to respond to human needs but also to extend the function of their elements. For instance, building skins could have additional functions that could harvest water, cycle it, cool the interior spaces, produce biomass, capture emission or enhance ventilation. Materials could respond through mineral air-purification properties, thermal storage capacities and skeletons as natural light conductors or kinetic energy stores. The correlating matrix offers many impulses to cross think as to how the built environment can be higher interrelated to ecological principles as a collaborating instance rather than as an exploiting facility.

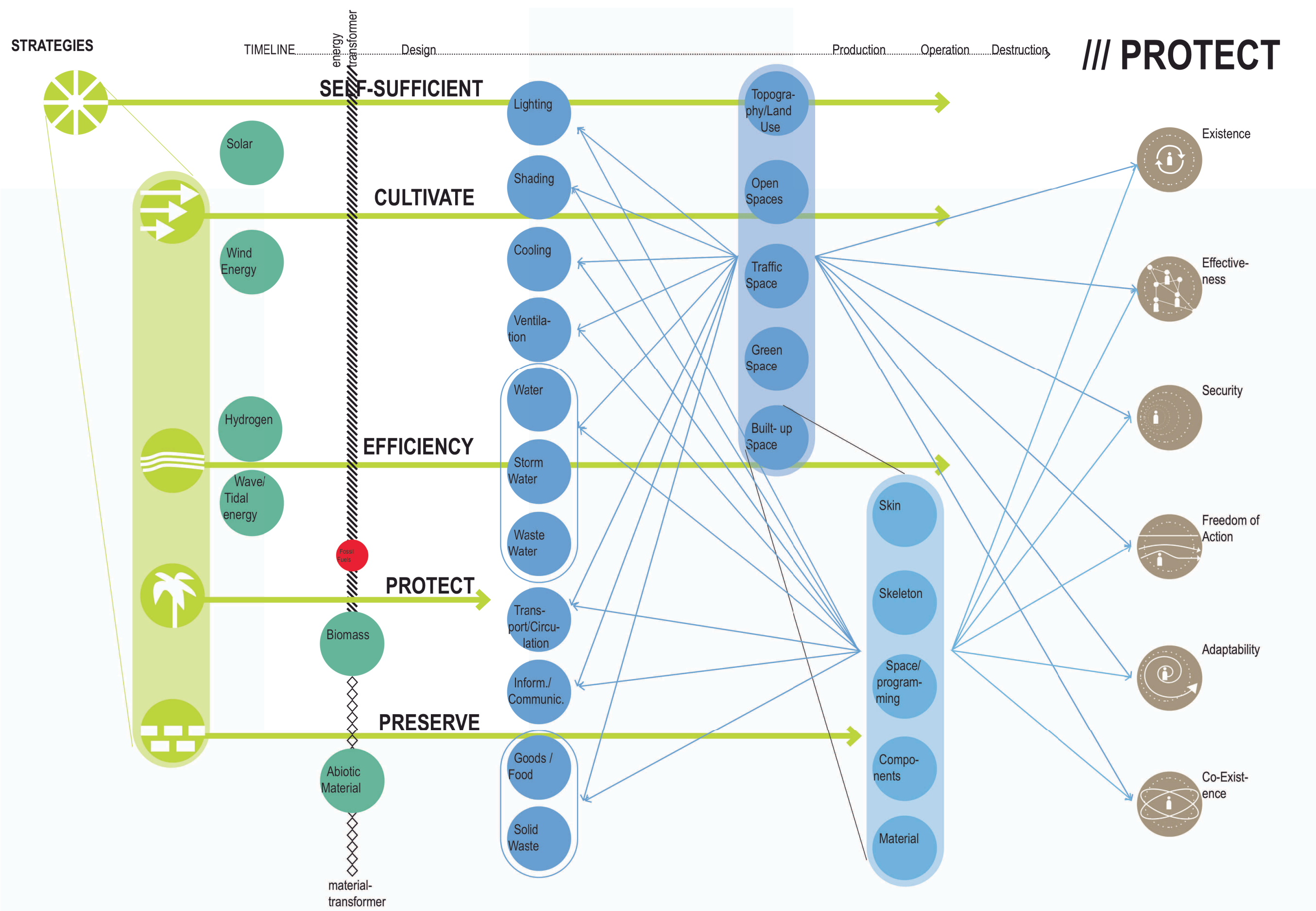


Figure 83→ Strategy complexity: Protect

Protect: More interconnection intensive than the strategies to ‘secure’ and to ‘respond’, resumes the concept to protect. Here a timeline in the urban process is enrolled, to which the design, construction and operation need to comply. The throughput of flows is here more sensitively geared towards preservation, protecting and cultivation of resources, which demands self-sufficiency in the urban system. Traditional oasis settlements resemble a good illustration for this category. The compact urban form minimizes land use and hence preserves available green space for effective agriculture. The surrounding eco-system is protected via the cultivation of dynamic resources into the static system. As a compound of cultivated farming and building it also serves the anthropogenic socio-cultural circumstances. When transferred into future orientated aspects of urbanism, energy efficiency can be reached through decentralised self-sustainable clusters: e.g. through micro-generation of renewable energy conversion on smaller scales (solar water heating, wind, ground source heat pump, biomass, hydro, fuel cells, micro combined heat and power) combined with smart grids for a demand based water and waste management. 'Intelligent[40]' buildings could provide an effective and supportive environment where a combination of high-or low-tech (passive solar heating, use of daylight, natural ventilation, natural cooling systems) utilises the building components (e.g. building envelop as productive energy transformation (solar skin), Co2 capture (through lime based materials), biomass producer (envelope as farmland), energy converting construction materials.

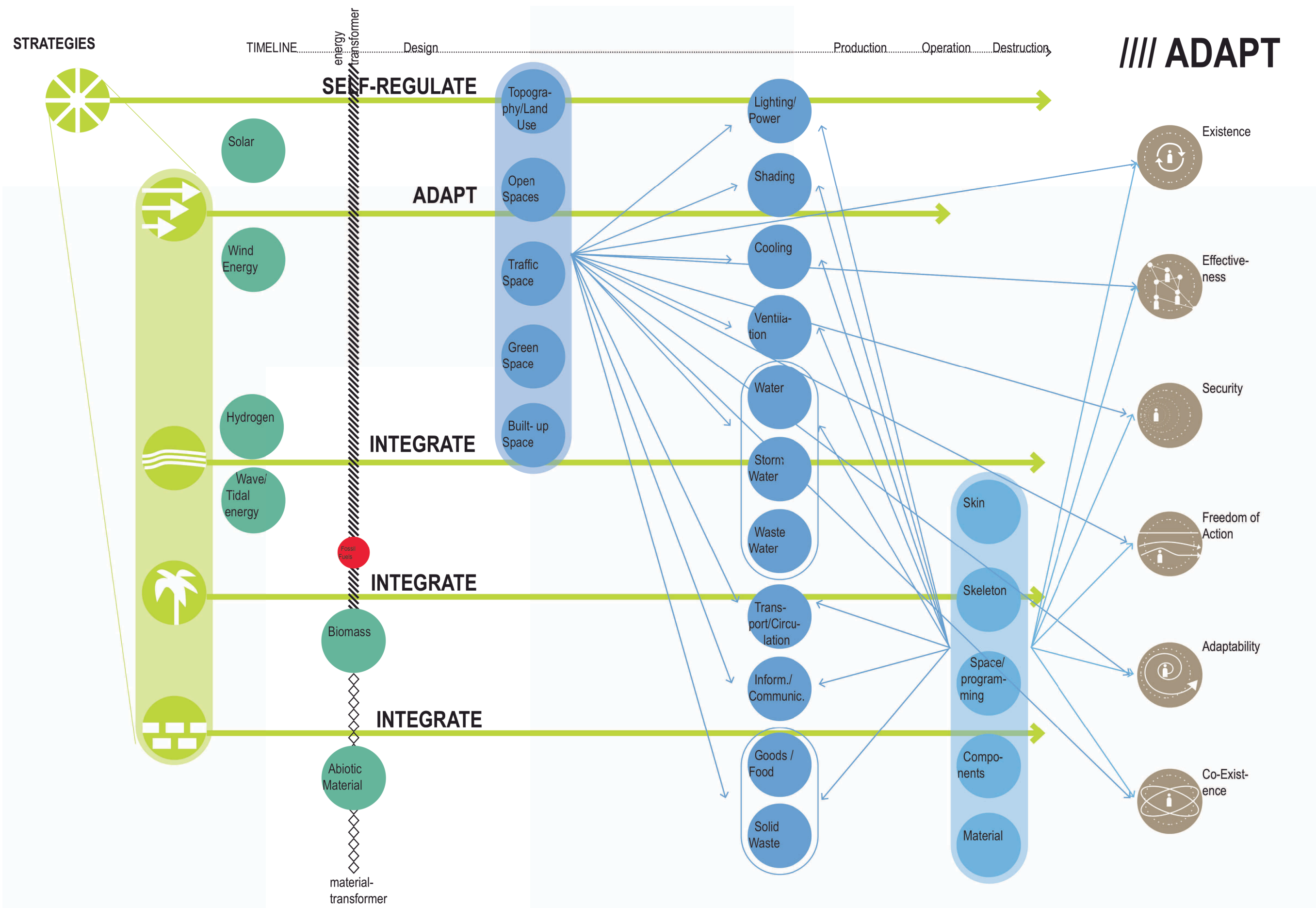


Figure 84→ Strategy complexity: Adapt

[40] The current use of 'intelligent' or 'smart' buildings or infrastructures describes a feedback based flow (matter, energy, information) throughput of resources according to demand.

Adapt: The strategy of adaptation resembles a combination of all of the strategies previously discussed concerning metabolic and self-sustaining systems strategies and extends them further into a self-organising systems. Flows in cycles, networks and nested systems of the built environment are asked to integrate (not just preserve or respond) to the ecosphere and anthroposphere. 'Smart' urban planning becomes a whole new multi-facetted interface for ecologically coherent cities. As illustrated in the diagram of Figure 84, resource throughputs have to be catered for by urban and architectural elements. That means that urban and rural areas merge into cities as contributors or even producers rather than consumers of arable land. Co-ordination of planning and management activities enables self-regulating processes based on various semi-lattice feedback networks at the all stages (from design to destruction) on all stakeholder instances. Design strategies may be modelled as an extension of ecosystems to achieve integrated through-puts of energy, material and information flows. Nano level technologies shall facilitate integral use of physical, biological and chemical properties (e.g. Bioremediation: uses microorganisms, green plants or their enzymes to remediate contaminated land) in order to cover the demand of resources accordingly. Urban systems may become a co-existing network of adapted cycles where an ecological memory needs to be shared by its population as active sub-systems in an organism like a semi-lattice organisation structure.

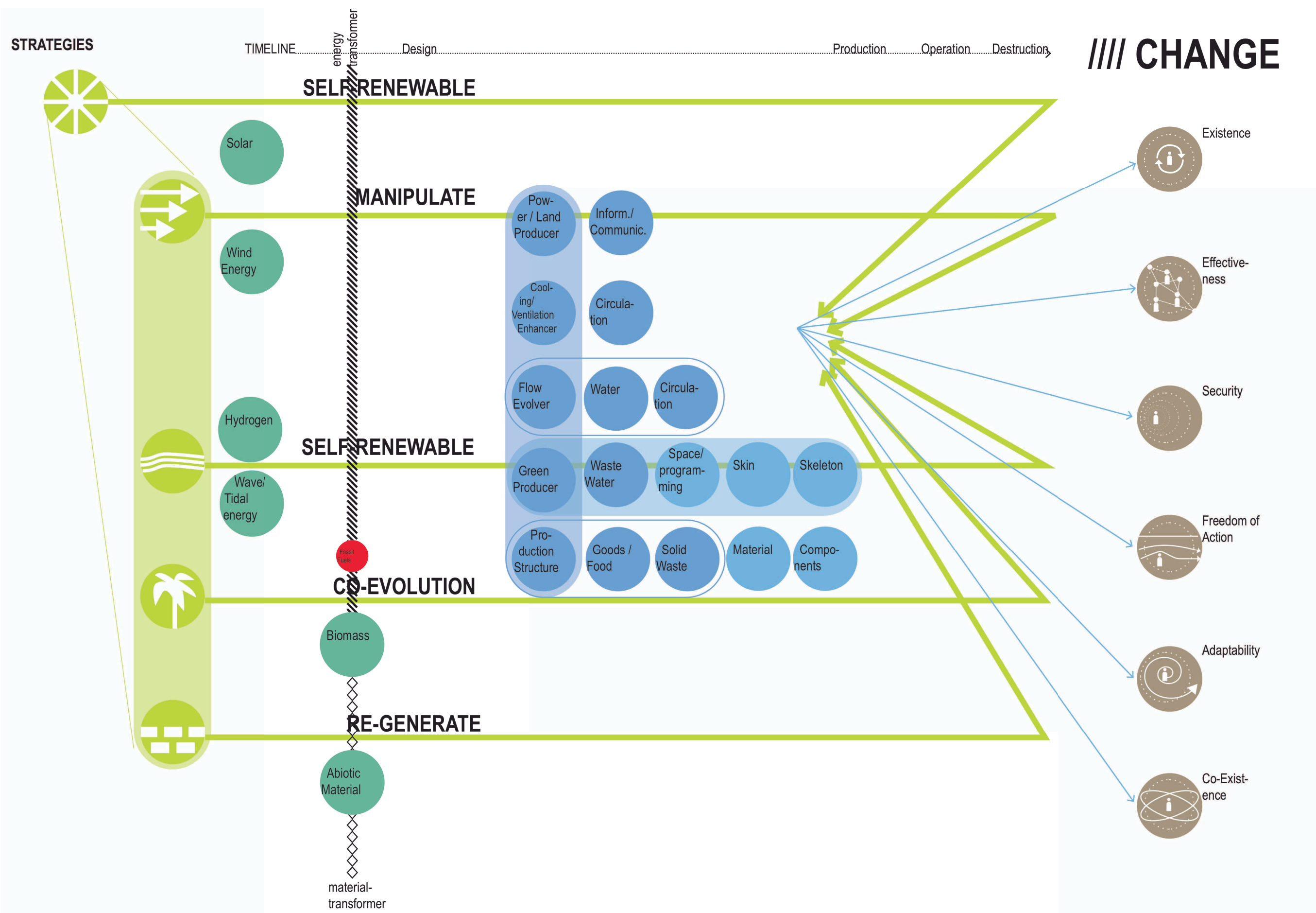


Figure 85→ Strategy complexity: Change

Change: The last proposed hierarchy of strategies of connectedness resumes the quest for self-renewing urban developments. Here the built environment may actively create or restore the capacity of the ecosphere. Our current making of cities may have to be changed to achieve this goal. That means that functions of architecture and urban environments have to gear up for a completely new priority. Whereas the demand based on human system inherent properties still determines the urban system, on the proposed level, interconnectivity demands the use of urbanism as an instrument for ecological self-regeneration so that it basically co-evolves into the ecosphere as an even contributor rather than as a consumer.
An urban system may be organised into interregional linkages hosting biodiversity corridors. Buildings resemble a system of static and dynamic resources for an anthropogenic and ecosystems interplay. There the boundaries between the urban and architectural scale might vanish into fractal networks of organisms. Figure 85 tries to indicate the change in morphology of the previously clearly laid out elements, which define the architectural and urban scale. Here they become clusters, which are determined by the production and regeneration of natural resources. This analogy might even ask for an entire change of needed flows of resources. Maybe the self-generating urban system of the highest ecological correlation is based on other sources for power, matter and information? The rise of revolutionary research in the fields of ecologically integrated biology and chemistry may lead to results that might impact on the industrial revolution-based mechanical infrastructures of our cities.

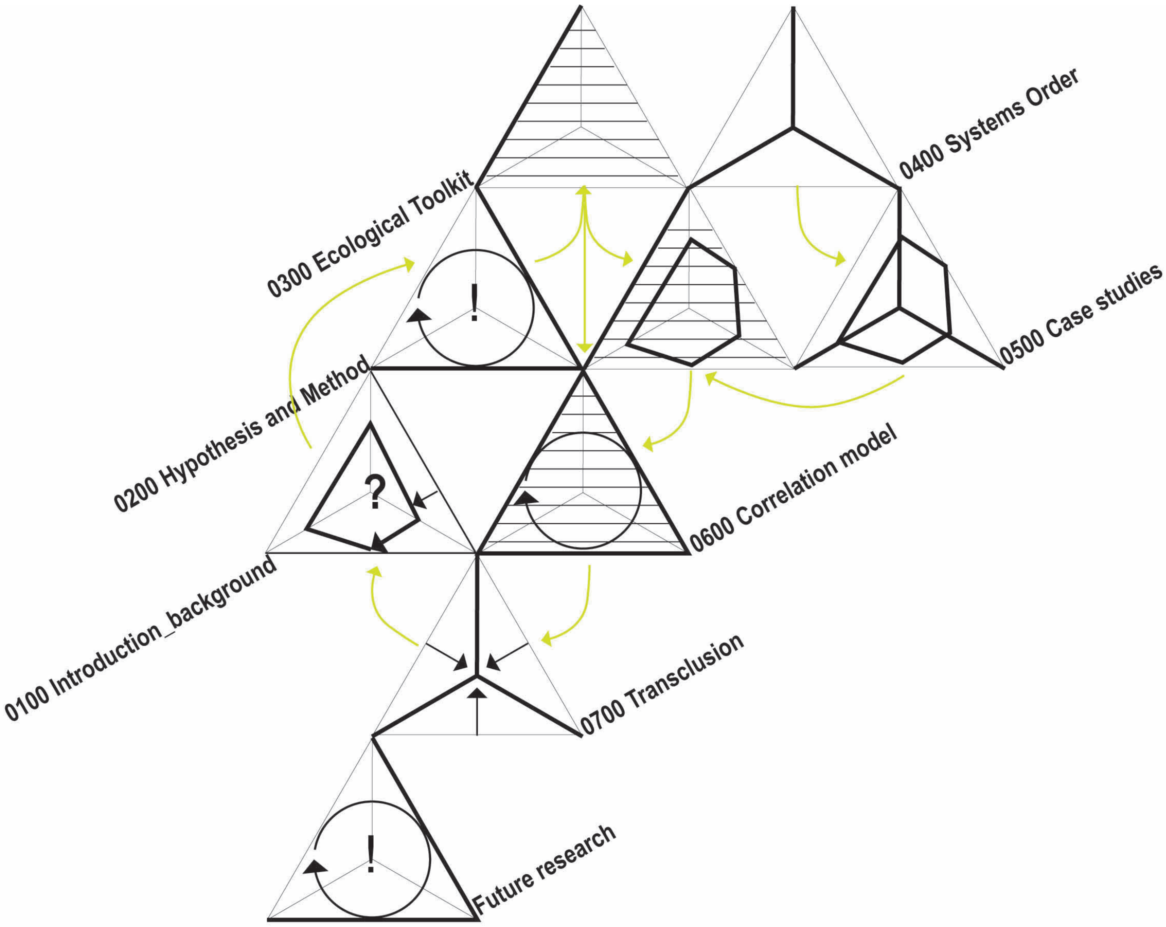
Change from Urban Revolution to Ecolution?

From Revo-lution[41] ('rolling back') to Eco-lution ('ecological coevolving'):
The most connected urban system would be the one that is able to co-evolve through self-renewing processes as nested networks in a dynamic balance with the ecosphere and anthroposphere. The archaeologist V. Gordon Childe characterized changes that led to the formation of urban systems from the Neolithic to the Industrial Revolution in his work 'Man 1932. The earliest states and cities that were influenced by interrelated social, economic, political, and cultural changes are here summed up in 10 traits shaping the 'Urban revolution'[42]. In order to reach this higher connectedness for a sustainable development (see also →0130), those traits might have to be questioned and related to the current challenges. Where large settlements and populations are described as a characteristic, in a model of higher ecological adaptability, polycentric clusters could have the potential to expand to a larger network. Full-time specialization and advanced divi-

[41] from Latin revolvere 'roll back'
[42] The phrase 'urban revolution' was also used by the philosopher and sociologist Henri Lefebvre (1901-1991) to refer to the production of space in relevance to the transformation of 'city' to the 'urban' socialization.

sion of labour has changed to part-time and time share activities, where generalists and experts network in service-based environments.
Production of an agricultural surplus to fund the government and a differentiated society cannot be afforded anymore. Effective agriculture needs to obey limited growth according to entropy. Also monumental public architecture, as symbols of manifested capital, could change into hybrid architectures with poly-functional features that are able to actively contribute to the production of energy and biomass. Competing companies have long ago replaced the monarchic ruling class. (Asynchronous) 'Writing' as a characteristic of the urban revolution has already evolved into (synchronous) digital networking. Exact and predictive sciences (such as arithmetic, geometry, astronomy, calendars) are currently changing into life sciences considering biology driven sciences, nanotechnologies, information technologies and regenerative sciences. Sophisticated art styles are overruled by approaches of re-producible design industries. Long-distance trade and the resulting contribution to emissions ask for local and regional self-sufficient exchange. And, finally, top down approaches by the state could become a co-evolving semi lattice structure, if argued for according to ecological system principles. As urban civilisation, we have overstepped the exclusive limits of 'man makes himself' and have risen to an exploiting enemy to ourselves. To adapt to this trend, we as architects and urbanists have to equally find inclusive solutions towards a dynamic balance to ecology, which could be established in an outlook of Urban Ecolution[43] where man does not dominate anymore but co-evolves.

[43] Urban Ecolution can be understood as a progressive proposal for a shift in perceiving cities in the 21st century considering a paradigm shift from resource consuming and waste producing urban environments towards ecologically adaptive urban support systems that serve the survival of the urbanized human kind.


0400 Systems Order
0300 Ecological Toolkit
0500 Case studies
0200 Hypothesis and Method
0600 Correlation model
0100 Introduction_background
0700 Transclusion
Future research

0700 Transclusion

> *'The power of abstract thinking has led us to treat the natural environment – the web of life – as if it consisted of separate parts, to be exploited by different interest groups. . . . To regain our full humanity, we have to regain our experience of connectedness with the entire web of life. This reconnecting, religio in Latin, is the very essence of the spiritual grounding of deep ecology.' (Capra, 1996, p. 296)*

Synopsis

Concluding[44] this work would require to 'completely shut' the so far developed thinking space. The Correlator as a model is in itself based on system principles, i.e. it implies constant adaptability and development. Hence the author wishes to extrapolate this thesis study with a trans-clusion[45] that thematises that a system is only an abstraction of reality, never closed and hence to be continued as Holling (→0310) describes it as 'panarchy'.

So far an abstract thinking space has been constructed that organizes the built environment in correlation to human and natural systems through the identification of ecological interconnection strategies. Desert oasis systems, as examples of self-sustainable settlements in resource scarce bio-climatic regions, are discussed in comparison to the contemporary trends of hydro-carbon based urban and architectural implications. Here the exemplified correlation strategies lay out the dilemma that a low interconnectivity between urban systems does not integrate ecological principles and hence contributes to climate change problems due to waste, pollution and resource exploitation. A higher connectivity on the contrary promises that the built environment will integrate, adapt, and finally co-evolve with(in) the ecosphere.

This study's aim is not to insert another theory into the growing jungle of sustainability debates of the age, which shout out new theories called: 'green urbanism', 'renewable energy city', 'bioregional carbon neutral city', 'distributed city', 'biophilic city', 'eco-efficient city', 'place-based city', 'the sustainable transport city', etc. The developed matrix of correlations (The Correlator →0600) acknowledges all of the above approaches, but asks how elements of urbanism are connected to those of eco- and human systems. All the concepts above can directly relate to the correlation matrix, which gives an overview of how the suggested concepts are ecologically interlinked and

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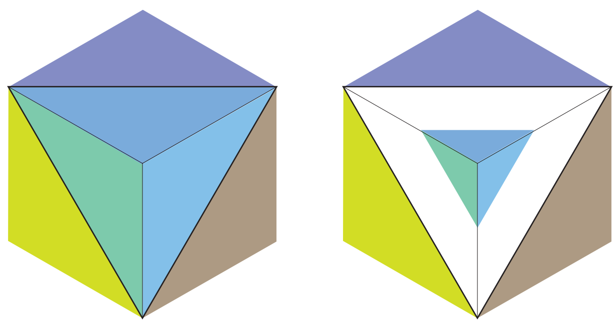
[44] from Latin concludere, from con- 'completely' and claudere 'to shut'.
[45] from Latin trans- 'across' and claudere 'to shut'.

what further potential linkages could be implied. The resulting knowledge should encourage the design or rather co-organisation of urban and architectural semi-lattices structures.
The Correlator presents areas of the built, natural and human environments that have the potential to be linked and also outlines strategies for the interconnection thereof. As it does not (yet) comprise a measuring system that can be applied in daily practise, the question arises: What next? Future prospects are discussed in the following section, considering the advantages of the Correlator as a model of interconnections:
Different implications on various Correlator inherent scales propose the transfer into simulation applications and also the consideration of systems technologies. (→0710)
Expandable cooperation is suggested for other support systems and also to other disciplines. (→0720)
This is followed by an appeal for future learning through research and development opportunities as well as transferring cities into generators. (→0730)



0710 Scalable implication

Relational rules of correlations have the opportunity to act as tools of urban planning and architecture, just like a building code. Building codes ideally allow maximum flexibility in local problem-solving and the design of a building, while integrating the building smartly into the urban fabric of the city as a whole.
The Correlator is itself scale-free. It defines how anything from a façade implemented material to an urban transit space can be interlinked to the available resources and needs to become compatible with the whole ecological system. As Mathieu Helie (2008) states: ‘The job of designing cities is not so much about determining form, but about defining the processes that will generate their form.’ The Correlator organises those different process flows, elements, and strategies as used in the planet’s natural environment into a thinking model of interconnectivity. The next steps would be to closely examine the possibilities of all urban and architectural flows and elements and the conversion into qualitative parameters thereof. This might lead to innovative products of process design regarding sun, water, wind, and materials, as well as a further formulation of multiple function materials. This work so far sets the principle basis of layers that can be interconnected in order to

reach a built environment that is viably and adaptively connected to the in-and output factors of natural resources and purpose driven by the human environment.

Modelling (the Correlator) on complex urban networks

As a further research step, it is useful to apply the correlating matrix to Information System Toolbox (e.g. via GIS[46] technology). Properties would have to be assigned to each of the (so far 3750 possible) interconnections which than could cumulate into the modelling of correlations via the Correlator inherent strategies (e.g. via BIM[47] technology).

Via graphical mapping of the link synapses (urban and architectural elements, human needs, and natural resources), an analysis as a measure of the quality of ecological networks would be possible, based on the identified linkage hierarchies (in an ascending order): reduce, respond, protect, adapt, and change.

As already schematically proposed in the analysis of the cases studies (→0500), a correlating analysis of the urban networks could map correlating links, identify missing links, and analyse the quality (in terms of ecological and anthropogenic interconnectivity) of the links.

Such a modelling simulation tool could be aimed at urban designers, architects, planners, geographers, socialists and environmental analysts who are interested in studying the quality of the system configurations of cities and architectures, and their related social and environmental processes. Small-scale components, detailed network analysis of architectural components, urban areas or even large-scale regional networks could be analysed in terms of their interconnectivity to human and natural systems through the scale-ability of the Correlator.

Beyond the identification of weaker or stronger interconnections of the urban networks it would then be needful to manage the improvement of interconnections via the strategic system concepts of connectivity as explained earlier in →0300. Those processes involve the leadership of governance institutions in order to assign decisions on the management of inter-connections, whereas bottom-up participation could always be possible on an information providing level.

This is where the research field of BIM and GIS mapping and information management become useful instruments to access, manage and interpret components of the urban network to all stakeholders. Platforms of information mapping could also be used to create awareness to the public and the trust in the network of professionals to deal with the networks under the possibility of participating via e-polls, giving space for informality whilst seeding certain processes via a top down decision.

Further on, strategic correlations could identify new fields for research subjects that are yet to be explored to generate self-renewing built environments (e.g. natural resource integrative facades,

[46] Geographic Information System
[47] Building Information Modeling

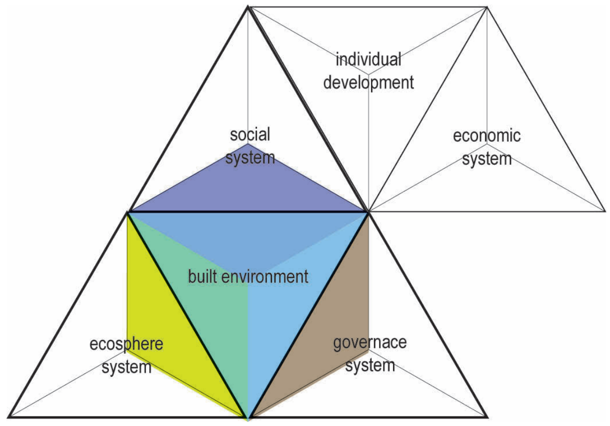
energy converting transit spaces, water treating open spaces, biomass based materials, carbon capturing foundations…).

Technology as glue?

Manifested in approaches like 'eco-cities', 'eco-architecture', and 'eco-technology', the question arises of how those 'concepts' are really linked to the ecology of the planet. As discussed in previous chapters, the industries involved in 'sustainable' development currently believe that technology can glue the built environment to the natural system. As a result those technologies are extremely specialized and non-integrated into multiple processes. They focus only on specific components within the complex network of interdependent elements and flows within the urban and architectural system. For instance technologies allow the reduction of flow throughputs, e.g. Water. Amounts are technically quantifiable and can be rated accordingly to prove success. On the other hand the questions of qualitative connection to soft factors like the proximity of water resources, (e.g. through water harvesting multifunctional facades, change of human comfort considerations, change of water as needed resource) or even if available infrastructural elements (e.g. pipe cross-sections to enable lower throughput) support the strategic goal are often not questioned. This leads to punctual manipulations that are not integrated into the bigger system because of neglected collateral dependencies. Seeing the built environment as a correlating platform could establish the recognition of complex adaptive behaviours in simple interconnected systems. In addition, adaptation depends upon a constant learning and improvement via feedback loops of information and knowledge.

Future intelligent systems technology

Hence, in the digital age where information flow and feed-back loops can be computed, stored, and reconnected, a fusion of synthetic (smart grids, smart metering, information flow, etc.) and natural systems could be possible. Using such developments as tools could lead to highly adaptable and hence self-organisational and viable support systems that can generate and evolve forms, shapes, and spatial organisation, production/fabrication, and operations. A new nature of built environments could advance through combining biological and synthetic human-made systems into adaptive and viable organisms.
Those future aspects of rethinking built environment also implement the restructuring of education in terms of methodology and content. Future professions need to be able to execute the mission to generate integrative self-renewing environments. →0720 →0730



0720 Expandable cooperation

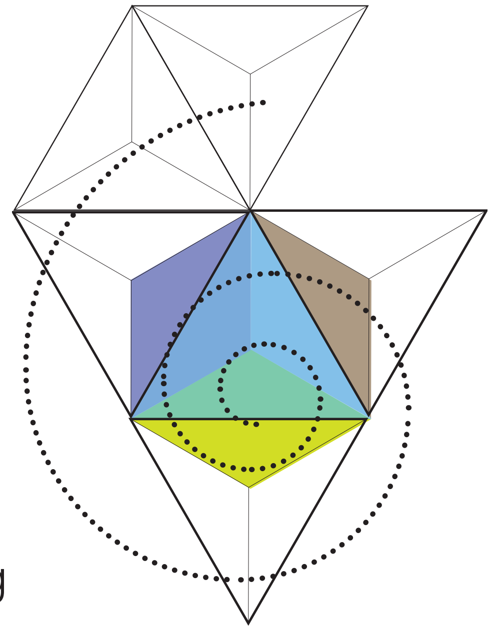
This work highlights the logic of the built environment in connection to its surrounding systems and sub-systems. As a fractal, the discussed built environment resembles one sub-system of the societal system. Others can be identified such as governance, economic, social, ecosphere systems, and individual development. As a correlating system, the thinking space of the Correlator is expandable with the same inherent correlation strategies as other sub-systems. Those rely on the embedded logic of viable ecological systems in the same way. The correlating matrix already includes the bordering systems of ecosphere and the social system as determining boundaries for architectural and urban systems. Another example comprises the governance system, which has direct influence on building codes, planning standards, and urban frameworks on a political instance. The overall feasibility of a paradigm change towards an ecologically viable development depends heavily on such governance policies. The proximity of their success rules the influence of the economic system where policy-making rules can be dependent on economic flows, which again determine investments in infrastructure, technology, and urban developments. In the language of the correlation matrix, this means that components of an economical system comprise of commerce/trade, labour and employment institutions, whilst transformation (technologies) relate to production and consumption processes e.g. resource refinement processes and flows resemble market goods and products (as outcomes of the transformation process) in combination with the trading of financial and information flows.

The question of authorship

Correlating the application of different problem domains requires a shift from the quantitative thinking specialist to a qualitative interdisciplinary network of domain experts within the homogeneous field embedded in the higher level of subsystems, thus raising the question of authorship.
Applied to the urban system, the role of the urban planner and architect needs to be that of a matchmaker of different disciplines that draws integrative solutions together. The authorial approach of providing a master plan; where specialists for infrastructural services, landscape design, mitigation, traffic flow rates etc. implement their requirements, might be utterly in-effective towards

the process of creating synergies. Such synergies will not have one noted author, but a team of different professions that find solutions together in order to avoid unnecessary double standards and resource consumption.

To answer the question of how to implement the strategies, as discussed in Chapter →0600, an understanding of inter-dependent participating disciplines is equally important. If the city and the individual buildings become active producers and contributors to the environment, a team of urbanists must be counted amongst planners, designers, and multi-disciplinary experts like anthropologists, agrarians, socialists, policy makers, biologists, hydro-geologists, bioengineers, process-engineers etc. The arising preconditions of making cities of the future, through including all the levels as described in the correlation model, requires a hybrid platform of thinkers that are willing to engage their energies into the process of a producing entity rather than in an outstanding product with which one name or label can be identified.
This thinking in correlative systems automatically implies a refrain from authorship and hierarchy of the proposing party. The question arises of to what extend the architect and designer still remains the founder of space and shape, but rather now represents a facilitator for relationships and processes with, and in, the built environment. Co-productive design is not based on fixed spatial components anymore, but on enabling processes for transitions and transformations within the built environment as a support system.
At the end our cities must become active contributing partners to the natural environment, not crouching consumers that oppose obstacles in the evolution of nature and mankind.



0730 Transferable learning

Beyond securing their existence, human kind has managed to invent tools for higher efficiency, cultivation, and prosperity. As we have learned over more than 10,000 years of civilisation, limits of the ecosphere threaten our current demand for growth. As a next step we need to adapt to, and evolve as, likeminded ecosystems, which implies the ability to change the current urban system structure and to be able to adapt to changes through constant learning. Those are qualities that are already inherent in human organisations. Current trends of cities and architectures work on static principles to protect its effectiveness as laid out under pre-dated conditions. It is necessary to approach the built environment as an extension of the natural system, by basically enabling flows of resources and energies through

a synergetic compensation system. Comprising in this work of urban and architectural systems, dependencies of elements and flows within the built environment can be withdrawn in the correlating matrix. The more connections that are possible, the better the compensation system will be adaptable to change and is therefore resilient towards the limits and properties of the ecosphere.

Learning and collaborating

In order to learn of the opportunities of how to implement such connections, innovative science and technologies of other fields can be consulted. As the 'waves of innovation' (Figure 86) established by the natural edge project in 2004 indicate; the current state-of-the-art science has already reached the era of ecology, biology, and 'whole system science'. Despite evolving sciences, cities and architectures seem to stand still on technologies, processes, and materials of a mechanically driven 20th century.

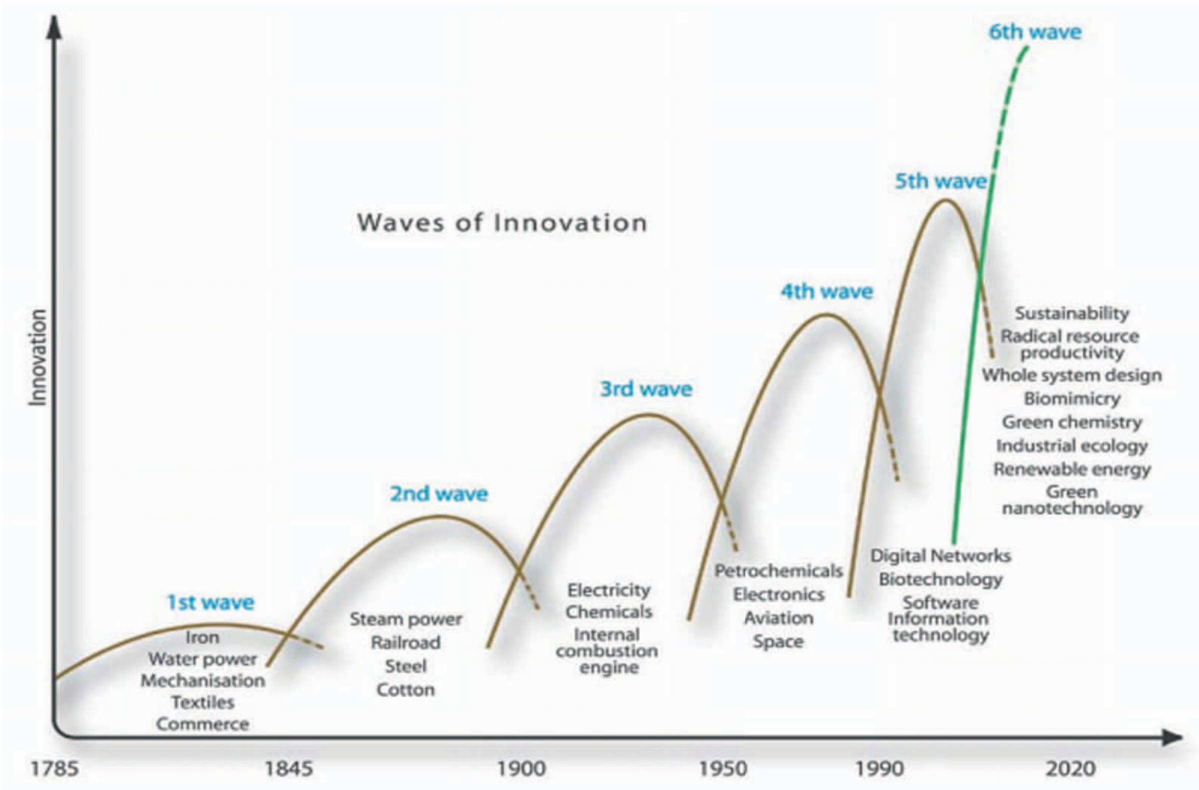


Figure 86→ Waves of Innovation of the First Industrial Revolution
The natural edge project (2004)

We live in a time of Bio-engineering, Biohacking, Artificial reproduction, Transplantations, Virus inventions, Glowing rabbits, Growing materials (bones, skin), and culturing of biotic and abiotic tissues. Referring to the strategy of change (→0335) there could be manipulation opportunities through the 'bio-chemical-genetic science' age for building materials, components, urban agriculture, and the like.

Where the current discussion of 'sustainable' design in architecture is stuck in the practice of resource efficiency (mainly through the strategy of 'reduce' for carbon sequestering solutions) on a technical expertise, much can be learned from the ecological system principles. Sophisticated techniques of animated design and information flow, in combination with the merge of natural and synthetic dynamics, are already in place in other sciences as exemplified above. Engineering has long evolved into new disciplines concerning living organisms (e.g., prosthetics in bio-mechanical engineering), agricultural, and bio-systems engineering. Creative co-operations with such emerging living organism research can devise new approaches of designing architecture towards a supporting bio-system. That means for the tools of transforming natural resources into or within the urban system, an active fusing of biotic and technological sciences in bio-engineering could be learned of and collaborated with.

Architects and urban planners should learn and collaborate with virologists, neuroscientists, computer scientists, physicists, and chemists to develop opportunities for architecture and urban design to collaborate as an ecologically self-renewing system. This learning as collaborative approach also requires a shift in education and research programmes and their methods used thereof. Especially the field of architects who have always been the interface steering entity of infra- and structural system, anthropogenic needs and demands within a social and ecological context are predestined to become the correlating axonists[48] for networks of the built environment. Hence rather than focusing on form and shape as aesthetic objects, relationships of cooperating parts of an overall metabolism needs to be of focus from which process redundant and resilient forms may be generated.

In order to follow the quest to design our built environments as co-evolving systems, and in facing the fact that our population has long reached the capacity limit of the planet's natural resources, the strategy of change (as discussed in →0630) requires the acknowledgment of traditional self-sufficient urban systems.

Urban and architectural systems as generators: The Correlator as enabler for Urban Ecolution

The living systems' approach reminds us again of Frederick John Kiesler and his 'Correalism' (1938) as sequenced in the opening chapter (→0100). He recognises 'Bio-technique' as a force for re-generation of the technological environment and makes architecture responsible to achieve re-generation:

> *The floor on which one walks, the chair on which one sits, the bed on which one rests, the wall that protects, the roof that shelters, and all other units of the man-built environment are significant for what they are: but they also possess nuclear multiple-force. It is commonly assumed that these are dead objects; actually they represent an interplay of action with one another and with nature. (Kiesler, 1938)*

In the end the Correlator as a reference matrix of interconnections can be used as a tool to identify relevant components of architecture and urbanism, ecospheric resources, and human needs, but the detailed work to change the built-environment into a co-evolving generator for humans and nature has yet to trans-clude.

Unfortunately fortune-driven free market economies do not view this as an imperative for value. After all that has been done by researchers, scientists, and activists towards finding environmentally adaptive solutions for our ways of living over the last decades, just the recent outcome of the UNFCCC COP19 shows the almost impossible goal of collaborating with the natural environment seriously. Concrete commitments[49] to combat climate change are now dissolved in volunteering (financial) contributions of member countries. Despite the 41 years old alarming report: 'Limits to

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[48] From Greek ax□n 'axis', connecting nerve synapses

[49] e.g. Especially heavy industry nations like China do not agree to any commitments and are classified as emerging nations, whereas the US as a developed nation does not subscribe to any emission reduction commitment at all.

growth' (Meadows, 1972) it seems that participating United Nation members are not willing to learn; preferring the benefit of economical growth rather than establishing an uncompromised governance leadership body that takes charge of balancing human interaction with ecological systems to ensure co-evolution.

That is exactly where architects and urbanists have to re-think their involvement as service delivering consultants. As mediators between the eco- and anthroposphere of what Kiesler describes in the method of 'Biotechnique': 'polarising natural forces towards human purpose', the approach of reducing flows of resources is a good start, but facing the tremendous demand on mother nature by mankind is not enough. Following Karl Friedrich Schinkel's (1796) belief of where the dilemma of mankind and nature opposing dissolves in an evolutionary cycle:

> *'Die Architektur ist die Fortsetzung der Natur in ihrer konstruktiven Thätigkeit. Diese Thätigkeit geht durch das Naturprodukt Mensch.'*
> *'Architecture is the continuation of nature in her constructive activity. This activity is conducted through a natural product: Mankind.' (Schinkel in Peschken, 1979, Lehrbuch 35)*

As demonstrated in this work, other strategies to solve 'sustainable development' can be learned: responding to environmental conditions, cultivating an approach of self-sufficiency, getting to the stage of adaptable self-regulative urban systems, and finally enforcing compensation systems for human beings' comfort to co-evolve in a self-renewing manner with the ecosphere.

The Correlator and the knowledge of the quality of ecological network connections proposes an aide-memoir to de-specify the tunnel-visioned expertise of past innovations and prioritises 'Vernetztes Denken' for newly meaningful concepts for a new planning culture that enable viable urban and architectural development, not only within desert regions.

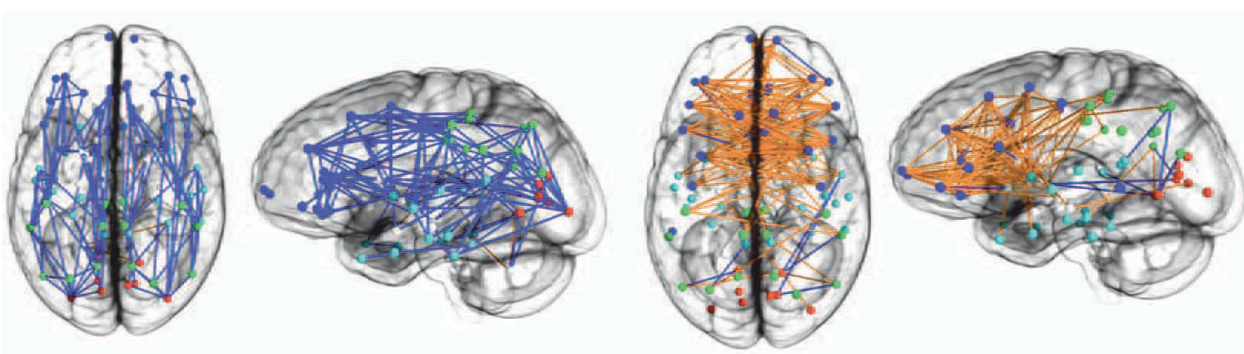
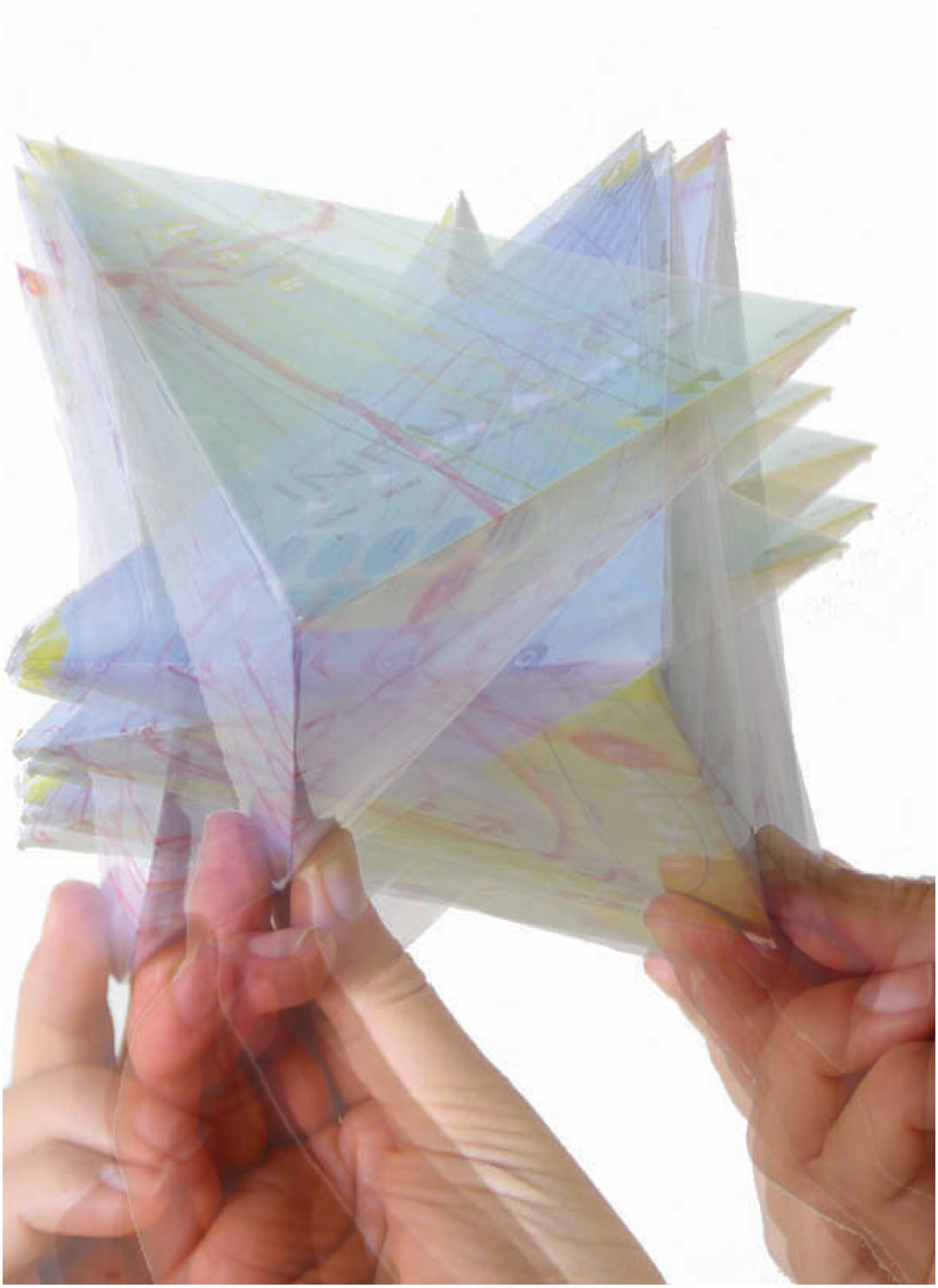


Figure 87 → 'Vernetztes Denken' Connection-wise analysis: Intra hemispheric connection (blue), Inter hemispheric connections (orange). Human brain network connectivity in males (left) and females (right). (Madhura, I. et.al. , 2013)



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Appendix

Appendix I

'Urban Comfort Muscat' Survey

Addendum to →0410 Human environment, Oman

Appendix II

'Traditional Building Knowledge' Research

Addendum to →0510 Traditional oasis settlement case study, Oman

Appendix III

'My home is my castle'

Addendum to →0520 Present urban settlement case study, Oman

Appendix IV

'Correlator' (foldable paper model)

Addendum to →0610 Forming the Correlator

Appendix I 'Urban Comfort Muscat'

Addendum →0410 Human environment, Oman

ISO's (International Organisation for Standardisation) thermal comfort standards are a common ground for expert engineers of technological building systems to implement thermal comfort through mathematical and physical equations. Hence, human comfort is supposed to be measurable and controllable through right technologies that pro-vide the perfect interior spatial climate according to fixed tables for the perfect-engineered climate. However figures for the perfectly engineered climate are mainly geared to serve temperate climate zones in Europe or North America. Hydro-carbon revenue in the Middle East has caused a massive influx in emergent cities on the Arabian Peninsula that are mainly served by 'Western' consultants and contractors. They use building codes and conducts as per established systems of their own countries without adapting to utterly different climatic and cultural conditions. In order to verify the figures as per the recognised standards as mentioned above, a survey about 'urban comfort' in Muscat was conducted in June 2012 (Summer). Around 260 surveys were undertaken at a market area in Muscat, As Seeb, on a day of average temperature 37 degrees Celsius, lunch time, with 69% relative humidity. Surveys were undertaken in three different spatial situations that are all not actively air-conditioned: shaded spaces, roofed spaces, and open spaces in a commercial area that is accessible to the public.

The pedestrians at the souk/market were questioned about their perception of temperature, ventilation, daylight, activity, humidity, Air-Conditioning (AC) habits, electrical light habits and their overall comfort feeling at the place at the time and given conditions. Most of those interviewed in a roofed climate felt neutral to the temperature, expected more ventilation, considered that less day light would be necessary, were equally happy with walking and sitting, felt neutral to the relative humidity, would have the habit to turn down their AC's at home to 14 degrees Celsius, would seldom use electrical lighting and felt overall neutrally comfortable. The situation was different when it came to the shaded spaces: temperatures were also perceived as too hot, more ventilation was desired, less daylight required, most of them were sitting, felt high humidity, would set their AC's at home to around 17 degrees, would also seldom use electrical lighting at home and felt overall neutrally comfortable. Interviews in open spaces revealed that temperatures were perceived as too hot, ventilation as too little, daylight as too much. Whereas most of the interviewed people who were sitting also felt high humidity, were lenient towards AC's set to 17 degrees, more use of electrical light than the ones interviewed in other spaces and felt overall less comfortable. In the following the survey questionnaire and the data analysis are shown.

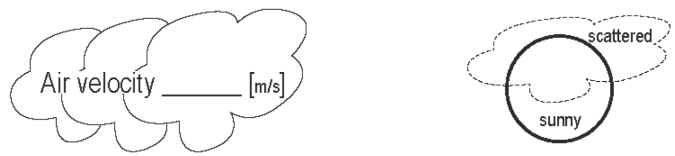
Research participants:Yomna Ashraf, Nikhil Chesian, Mohammed Timami, Yasir Otbi, Sulaiman al Harthy, Meriam Osman, Ahmed al Hatmi, Khawlah al Salmi, Maram al Balushi, Habiba al Shaqsi, Safa al zShkairi, Hawa al Harrasi, Fatma al Harrasi, Aseel Elgib and Widad al Shabaili.

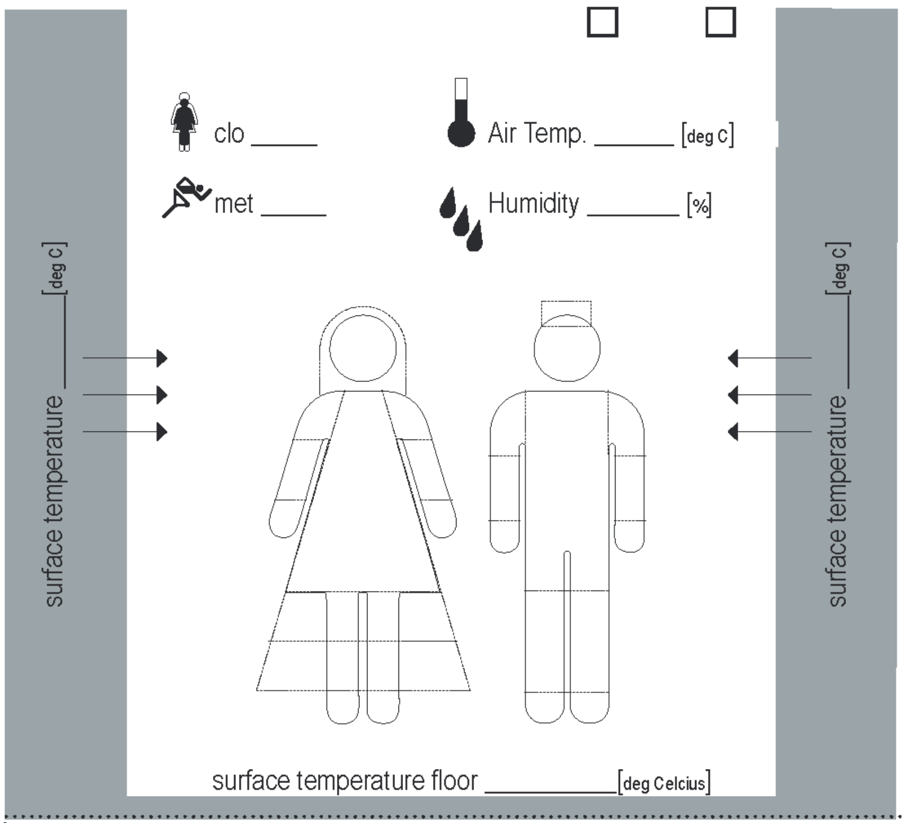
UPAD Urban Comfort Survey June 2012

Student____________________ID#________________________

Date____________________Time________________________

Location____________________N____________E______________

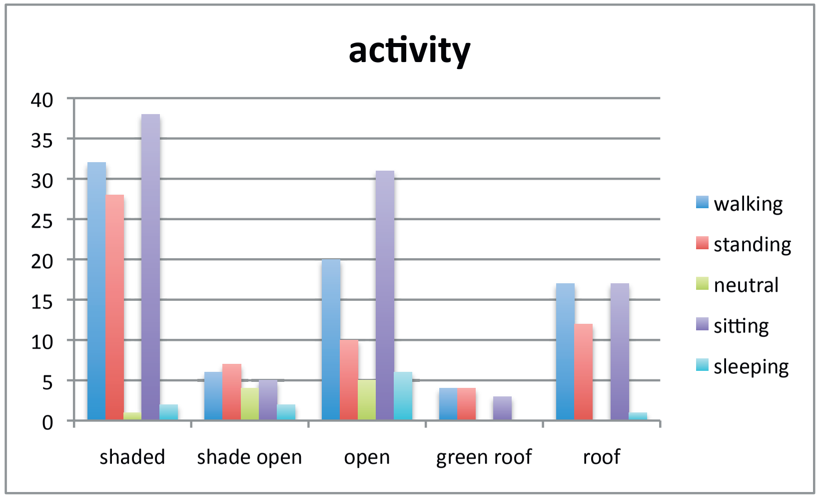




Question			neutral		
TEMPERATURE How do you feel dressed as you are?	cold				hot
AIR Would you like more or less air ventilation around you?	more air ventilation				less air
SUN Would you like more or less sun/ daylight in the current environment?	more sun				less sun
ACTIVITY How active have you been the last 30minutes ?	sleeping	sitting		standing	walking
HUMIDITY How much humidity do you feel right now ?	high humidity				low humidity
AIR CONDITIONING What is the temperature of your AC at home?	14	17	20	23	26
LIGHT How often are your lights switched on at home during the day?	seldom				very often
COMFORT How comfortable do you feel right now?	not comfortable				very

Many thanks for your time!

Daniela A. Ottmann _ Assistant Professor _ ASD Architecture and Sustainable Design _ UPAD Department for Urban Planning and Architectural Design _German University of Technology in Oman (GUtech)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15
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25
30
35
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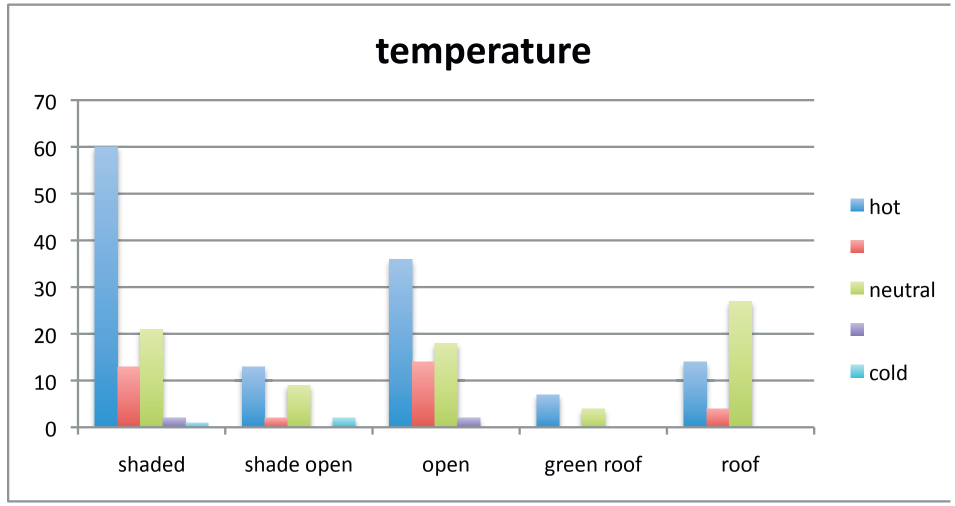
shaded
shade open
open
green roof
roof
walking
standing
neutral
sitting
sleeping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30
40
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70
shaded
shade open
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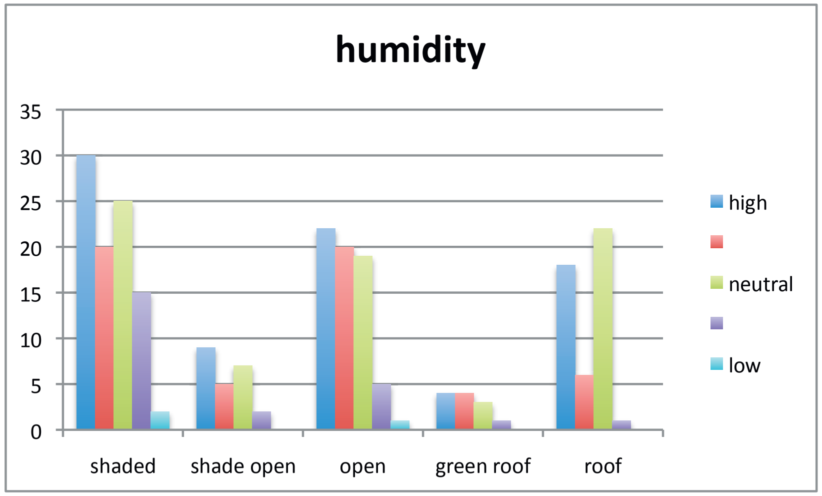
green roof
roof
hot
neutral
cold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15
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25
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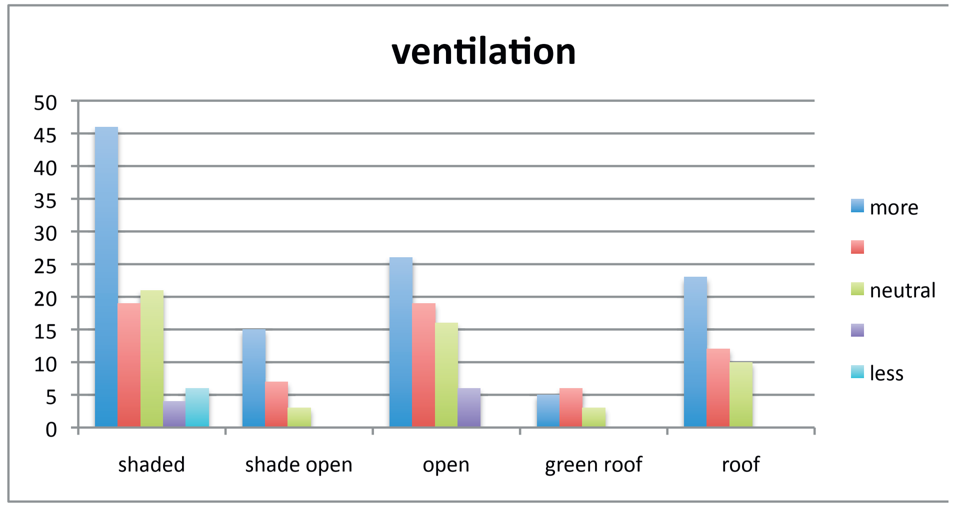
35
shaded
shade open
open
green roof
roof
high
neutral
low


ventilation
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shaded
shade open
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green roof
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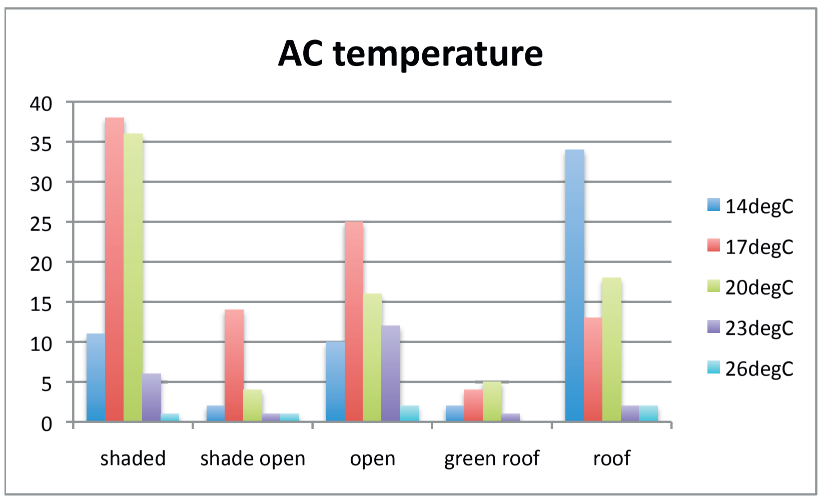
less


AC temperature
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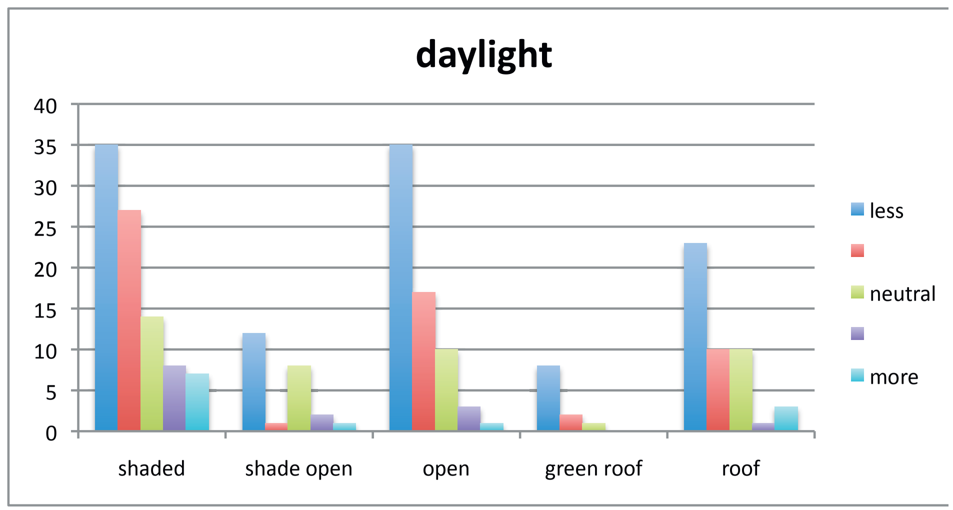
shaded
shade open
open
green roof
roof
14degC
17degC
20degC
23degC
26degC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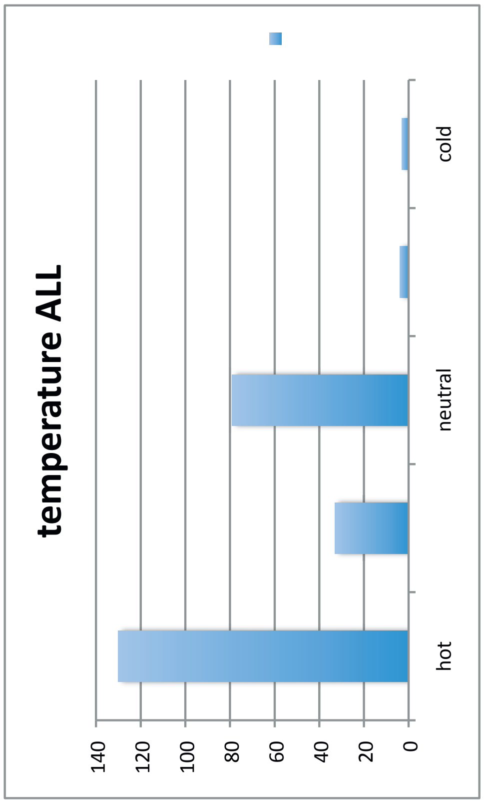
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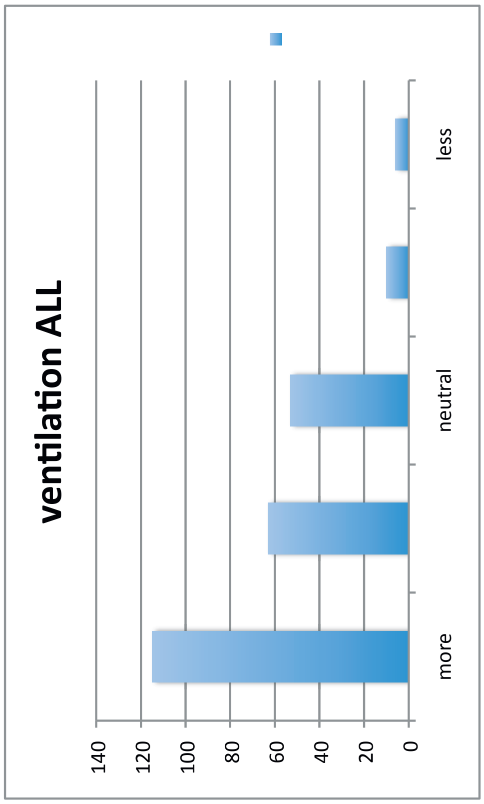
0
hot
neutral
cold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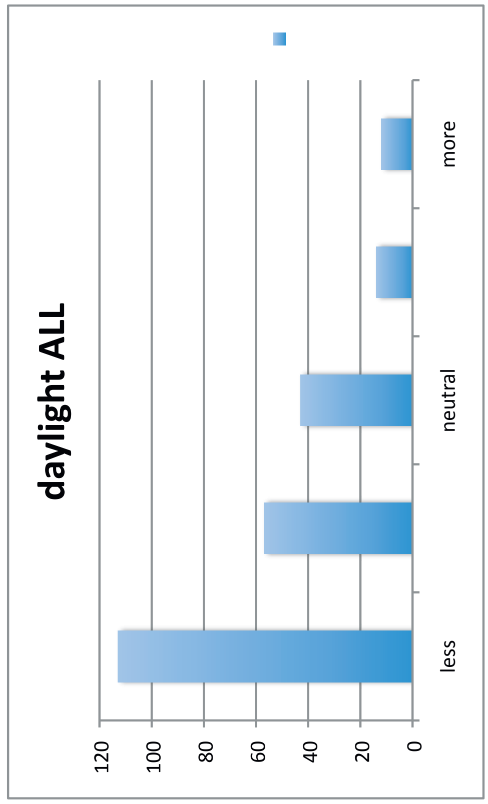
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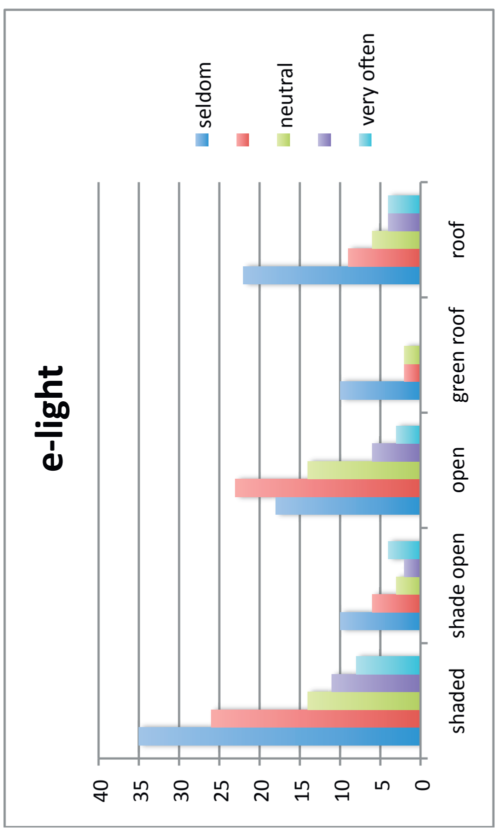
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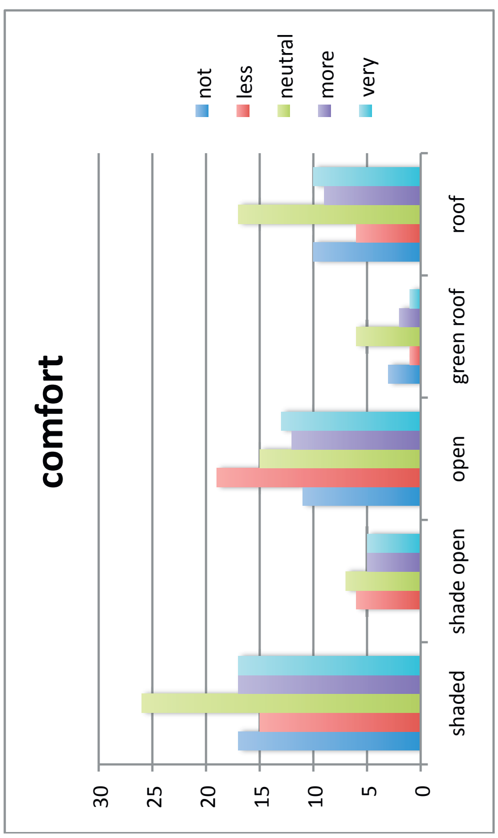
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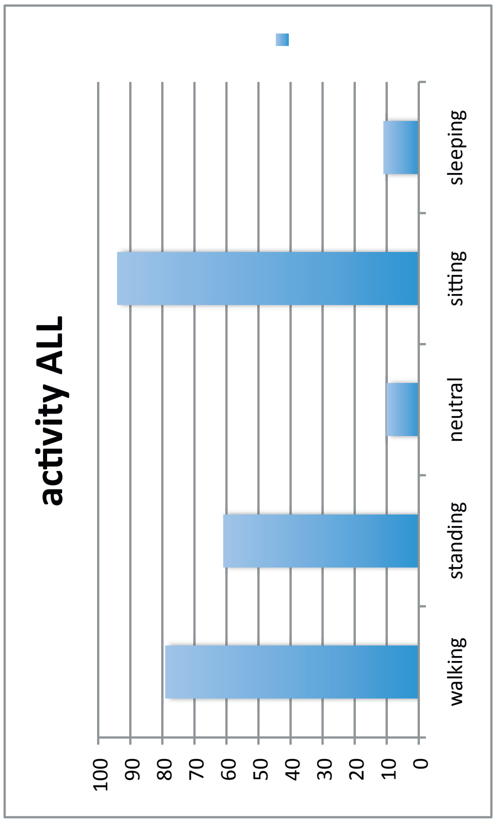
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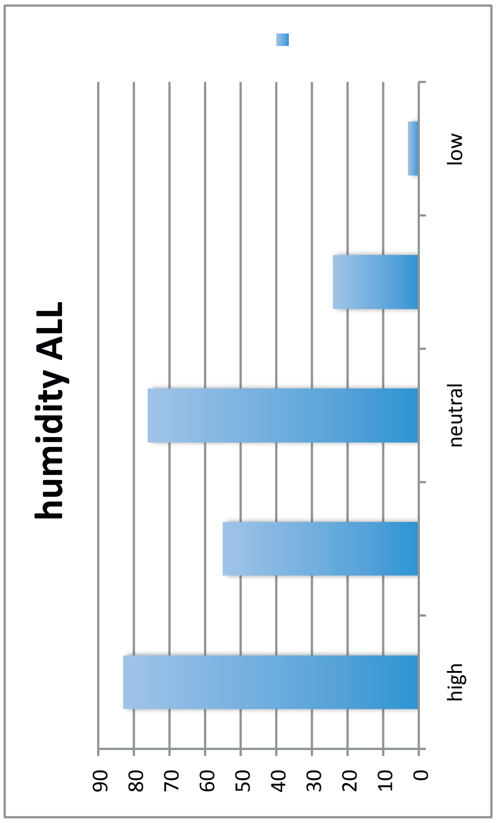
standing
neutral
sitting
sleeping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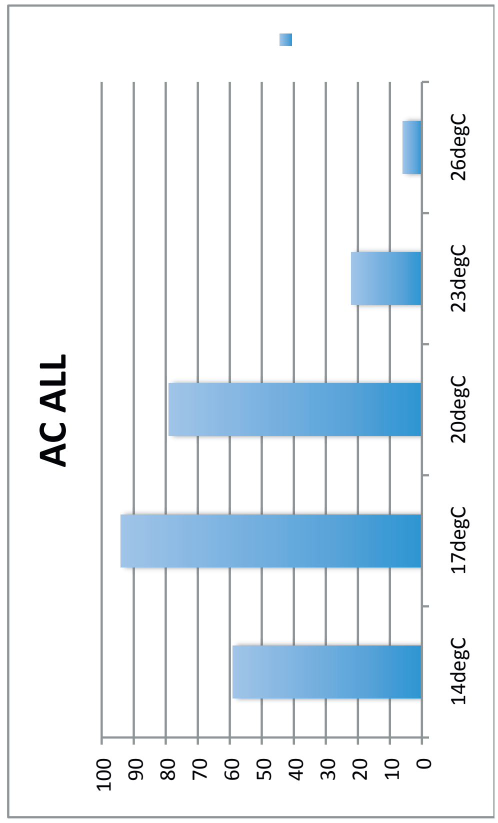
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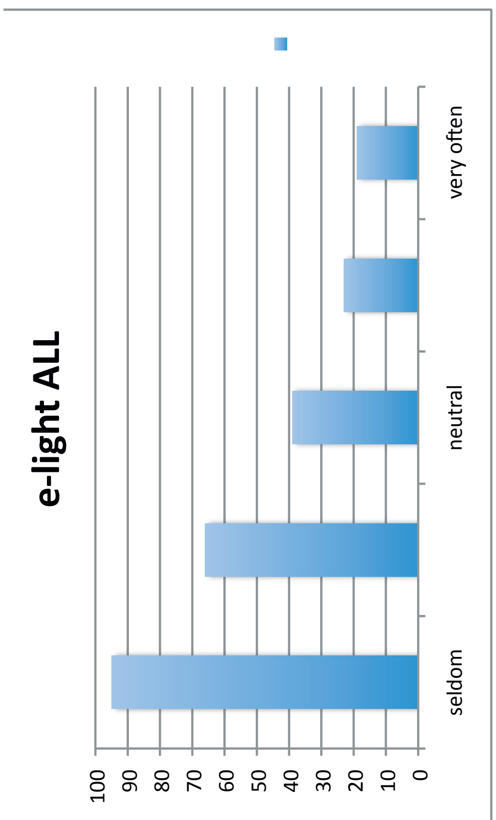
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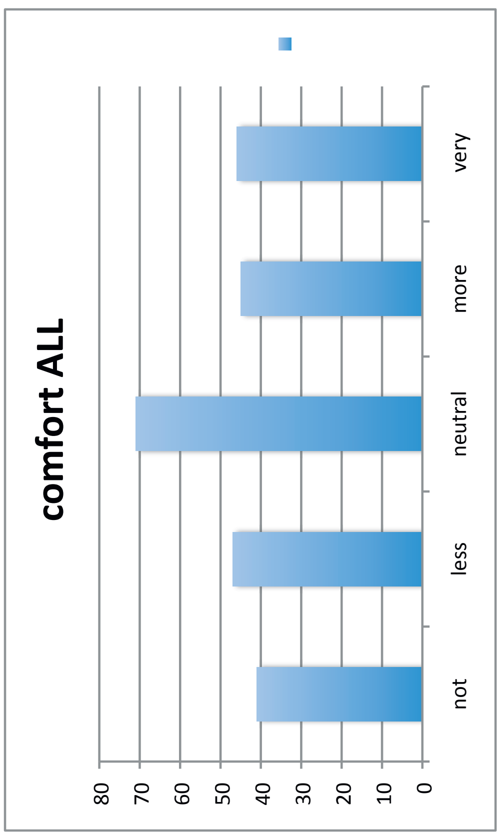
neutral
very often


comfort ALL
80
70
60
50
40
30
20
10
0
not
less
neutral
more
very

temperature		shaded	shade open	open	green roof	roof	
	hot	60	13	36	7	14	130
		13	2	14	0	4	33
	neutral	21	9	18	4	27	79
		2	0	2	0	0	4
	cold	1	2	0	0	0	3
						249	249

ventilation		shaded	shade open	open	green roof	roof	
	more	46	15	26	5	23	115
		19	7	19	6	12	63
	neutral	21	3	16	3	10	53
		4	0	6	0	0	10
	less	6	0	0	0	0	6
						247	247

daylight/sun		shaded	shade open	open	green roof	roof	
	less	35	12	35	8	23	113
		27	1	17	2	10	57
	neutral	14	8	10	1	10	43
		8	2	3	0	1	14
	more	7	1	1	0	3	12
						239	

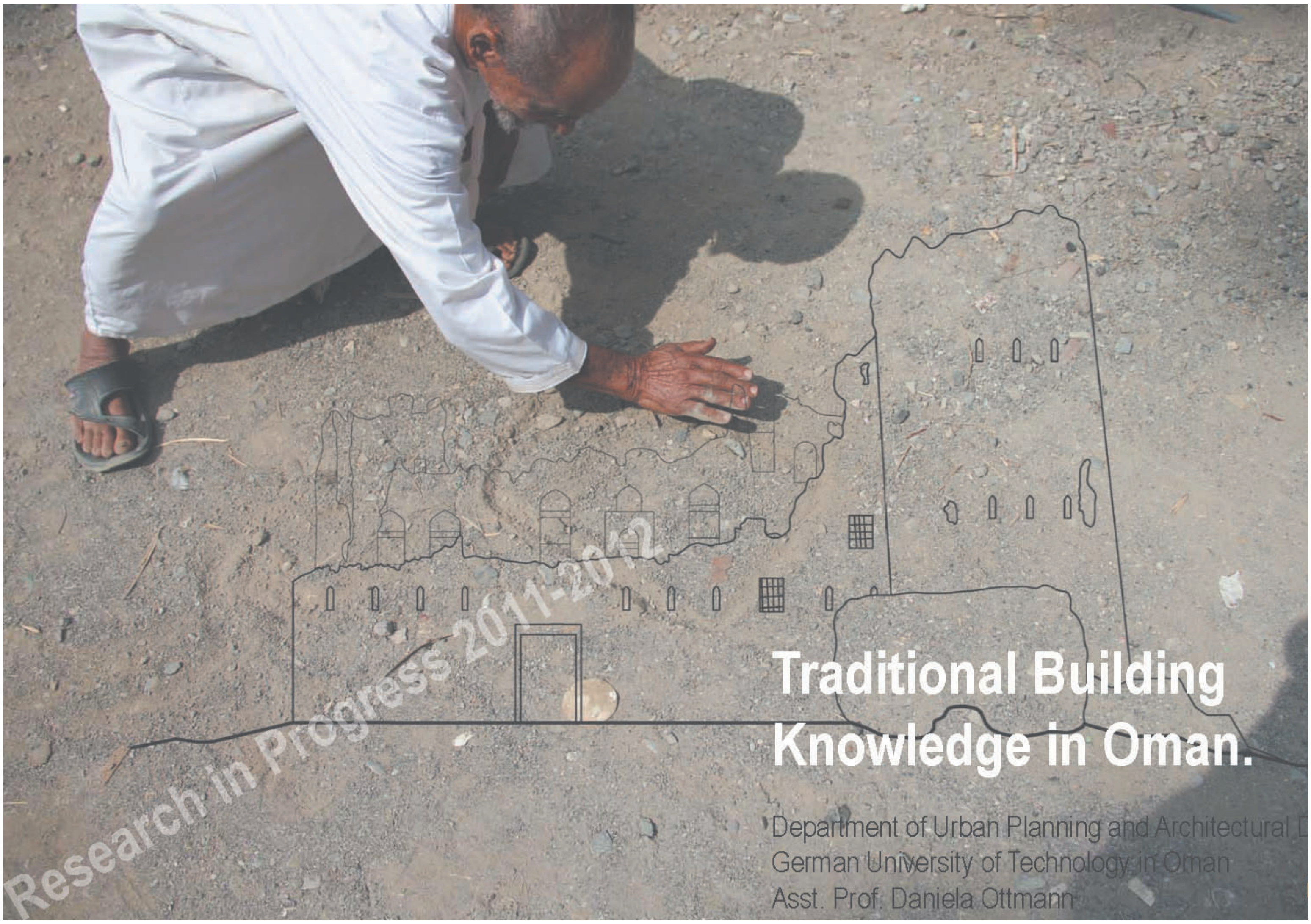
activity		shaded	shade open	open	green roof	roof	
	walking	32	6	20	4	17	79
	standing	28	7	10	4	12	61
	neutral	1	4	5	0	0	10
	sitting	38	5	31	3	17	94
	sleeping	2	2	6	0	1	11
						255	255

humidity		shaded	shade open	open	green roof	roof	
	high	30	9	22	4	18	83
		20	5	20	4	6	55
	neutral	25	7	19	3	22	76
		15	2	5	1	1	24
	low	2	0	1	0	0	3
						241	241

ac		shaded	shade open	open	green roof	roof	
	14degC	11	2	10	2	34	59
	17degC	38	14	25	4	13	94
	20degC	36	4	16	5	18	79
	23degC	6	1	12	1	2	22
	26degC	1	1	2	0	2	6
							260

e-light		shaded	shade open	open	green roof	roof	
	seldom	35	10	18	10	22	95
		26	6	23	2	9	66
	neutral	14	3	14	2	6	39
		11	2	6	0	4	23
	very often	8	4	3	0	4	19
							242

comfort		shaded	shade open	open	green roof	roof	
	not	17	0	11	3	10	41
	less	15	6	19	1	6	47
	neutral	26	7	15	6	17	71
	more	17	5	12	2	9	45
	very	17	5	13	1	10	46
							250



Appendix II 'Traditional Building Knowledge' Research

Addendum →0510 Traditional oasis settlement case study, Oman

Al Mansafah is part of the research on 'Traditional Building Knowledge in Oman' and was conducted in 2011 by the author and students of the 5th semester of the faculty of Urban Planning and Architecture at the German University of Technology in Oman. The research was structured to the following components:

- The oral history of old building masters in the region focusing on building materials, technologies and regulations.
- Case studies of selected traditional buildings in different regions of Oman.
- An archive of historical documents related to the case studies.
- Analyses of traditional planning and building regulations and the discussion of implementation into the 21st century thereof.

All those findings form the foundation for the analysis of the case study's inter connectivity of the built environments to the human and natural environment. In total there were 12 settlements included in this research, but only the part of Ibra (MFA) is shown here in this Appendix to explain the outcome scheme of the study. Research participants: Alisraa Al Saadi, Amr Al Zadjali, Asia Al Lamki, Asila Al Busaidi, Ayesha Rahman, Fatma Al Rahbi, Fouz Al Busaidi, Haitham Al Rawahi, Hamida Al Riyami, Hanan Al Riyami, Iman Al Ajmi , Khadija Al Mandhari, Mahir Al Arafati, Maiysa Al Mandhari, Maryam Al Taei, Mohammed Al Madhani, Nadeen Tall, Nasser Al Sayegh, Nibras Al Molahi, Noor Al Raisi, Ricky Vinayachandra, Rola Al Harthy, Sabreen Al Badai, Sabrina Ahmed, Saleh Al Adawy, Shadha Al Mazrouai, Shaima Al Raisi, Sultan Al Zadjali, Talal Al Haremi and Taleed Rose with the support of Dipl.-Ing. Yue Chen.

Traditional Building Knowledge in Oman.
December 2011

The students of the 5th semester of the Department of Urban Planning and Architectural Design under the leadership of Asst. Professor Daniela Ottmann, have been researching and compiling in a one semester fieldwork investigation the following:
1. The oral history of old building masters in the region focusing on building materials, technologies and regulations.
2. Case studies of selected traditional buildings in different regions of Oman.
3. An archive of historical documents related to the case studies.
4. Analyses of traditional planning and building regulation and the discussion of implementation into the 21st century thereof.

The mission of this research and analysis is to revitalise knowledge that evolved over thousands of years in Oman in order to transfer this knowledge into the future development of the country accordingly.

In an exhibition the results of the initial research are presented and in a conference contents are being discussed with the vision to analyse traditional building knowledge further in future scientific work.

CONTENT

Department of
Urban Planning and Architectural Design
German University
of Technology in Oman

Winter Term 2011

Traditional Building Knowledge in Oman

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Traditional Building Knowledge in Oman

A research project of Urban Planning and Architectural Design Students from the German University of Technology in Oman 2011

Project idea

The students of the 5th semester of the Department of Urban Panning and Architectural Design under the leadership of Asst. Professor Daniela Ottmann, have been researching and compiling on traditional Omani Building constructions throughout Oman.

The mission of this research and analysis is to revitalise knowledge that evolved over thousands of years in Oman in order to transfer this knowledge into the future development of the country accordingly.

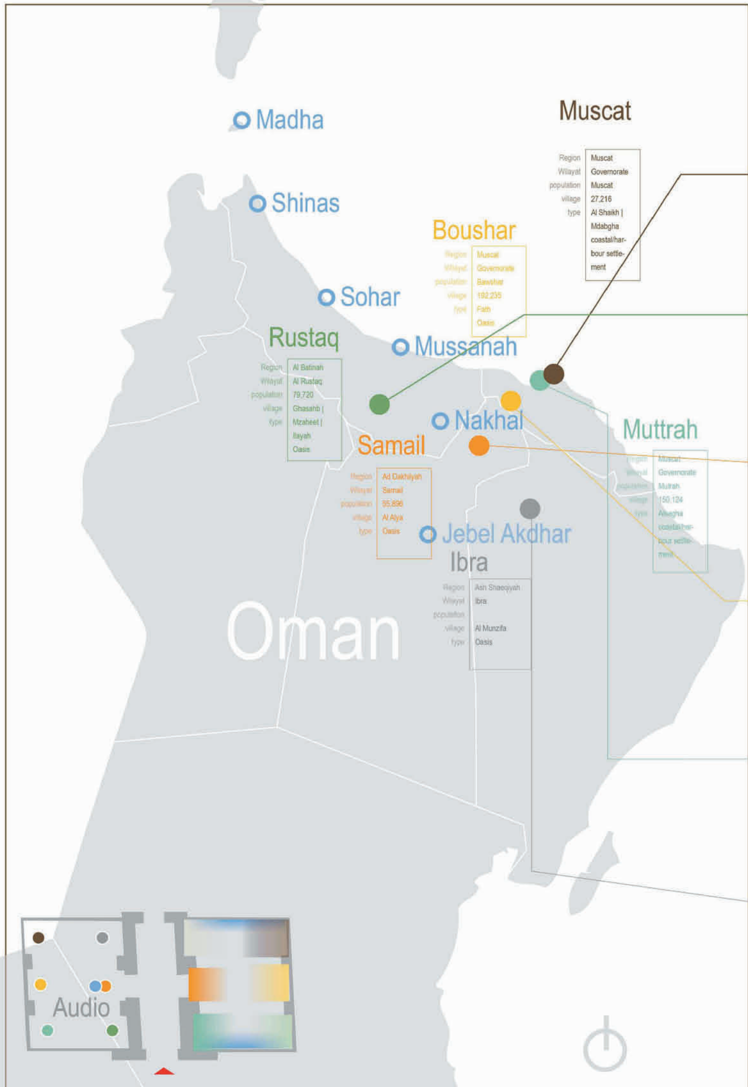
In an exhibition the results of the initial research are presented and in a conference contents are being discussed with the vision to analyse traditional building knowledge further in future scientific work.

Participants:

Urban Planning and Architectural Design students Semester 5 2011:

Alisraa Al Saadi, Amr Al Zadjali, Asia Al Lamki, Asila Al Busaidi, Ayesha Rahman, Fatma Al Rahbi, Fouz Al Busaidi, Haitham Al Rawahi, Hamida Al Riyami, Hanan Al Riyami, Iman Al Ajmi, Khadija Al Mandhari, Mahir Al Arafati, Maiysa Al Mandhari, Maryam Al Taei, Mohammed Al Madhani, Nadeen Tall, Nasser Al Sayegh, Nibras Al Molahi, Noor Al Raisi, Ricky Vinayachandra, Rola Al Harthy, Sabreen Al Badai, Sabrina Ahmed, Saleh Al Adawy, Shadha Al Mazrouai, Shaima Al Raisi, Sultan Al Zadjali, Talal Al Haremi, Taleed Rose

with the support of Dipl.-Ing. Yue Chen and under the leadership of Asst.Prof. Daniela Ottmann in conjunction of the courses Fieldwork and Arabic Planning Law and Sytems Winter Term 2011.



Process

Due to the scarce availability of documents referring to the knowledge of the traditional ways of building and planning settlements in Oman, the research undertook the following steps:

1. The oral history of old building masters in the region focusing on Building materials, technologies and regulations.

2. Case studies of selected traditional buildings in different regions of Oman.

3. An archive of historical documents related to the case studies.

4. Analyses of traditional planning and building regulation and the discussion of implementation into the 21st century thereof.

PROCESS

Interviews

Quote :
„The height of our area 'Helat Al Sheekh' is at the same height of Al Miranni fort ."
- Muhsen Hussain Noor Al- Raisi

Quote :
„I prefer loam as it is natural material from sand and we are born from sand , live on sand and die in sand"
- Salim Al Mandhari

Quote :
"قرين وازع مغطي على سمايل"
-Ghashim bin Said Al- Aghbari

Quote :
„The people of boushar act and work as one community and are always there for each other"
- Al Sayyid Qahtan bin Nassir AL-Busaidi

Quote :
„People in the past were satisfied by the little things not because they can't get more but because of their contentedness."
-Siddiq Dawood Ali Al-Sayegh

Quote :
„Arabs preferred to live close to each other"
- Said Salim Said Al-Gathi

Quote :
"الجبل الاخضر واحة امان في حضن عمان"
-- Salim Mohammed Houmood Al Toobi

Case Studies

Muscat

The topography of Muscat is defined by mountains which surrounded the area. From the sixteenth century until as recently as 1970, Old Muscat was a walled city where the gates were locked at sunset. We Interviewed Muhsen Hussain Noor Al Raisi. He gave us the Informations about the area, and we took two study Cases which located in Mudabge and Helat Al Sheek in old Muscat.

Rustaq

The wilayah of Rustaq is in the Western Hajar, in the south of the Batina Region. The name of the village is Mzaheet.

We Interviewed :

Salim Al Mandhari [Mzaheet, Mosque]

Hamdan Al Dhuyani [Alayat, General]

Zaher al Harrassi [Fort, Al Alayah]

Adullah al Adawy [AL Ghashb house]

Samail

Samail is surrounded by mountains and the village is almost covered by palm trees, the reason behind this name is when a storm came to this place everything has gone unless one farm called Samail. It's very famous of the dates the palm trees covers most of the area. We Interviewed Ali Salim Al Amri our study cases are located in Al Naya in Samil.

Boushar

is a mountainous area, it has sand dunes in the west past of Boushar and mountains in the east.
To cope with the climate, the houses were made out of thick loam material to absorb moisture and release it thus keeping the houses cool from the inside. It also has small openings at the top of each floor to act as wind channels for ventilation.We interviewed Qahtan bin Nassir Al Busaidi and did research ont Fort and residential Buidling.

Muttrah

is one of the old inhabitant areas in the region. And it's one of major trading centers because of its strategic place on the sea. Moreover the people who lived on the place were mostly traders who have their own houses and shops close to each other.

We interviewed Mr. Siddiq Dawood Al Sayegh and did the case study on souq and Al Hana Village .

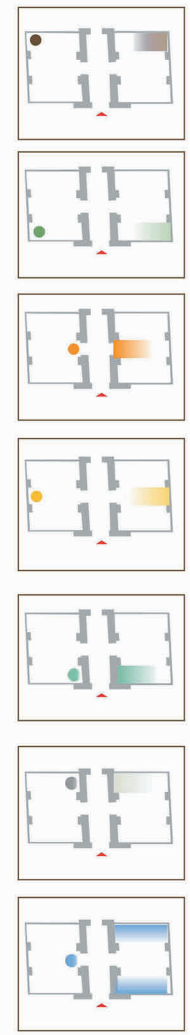
Ibra

Al-Munzifa was surrounded by a city wall with 35 gates. the gates lead to farms located around the city wall. the servants houses were located next to the gates, moreover there was a hierarchical pathways that connected the houses and public areas. In addition to wind direction, the houses were also built according to the stream of Al-falaj, to make water more accessible. we Interviewed Said Salim Said Al-Gathi. Our study Case is Al Munisifah

Various

various interviews and case studies were conducted throught following areas:

- Madha
- Shinas
- Jebel Akhdar
- Sohar
- Al Flaj
- Wadi Tayeen
- Musanaah
- Nakhal



[O] ral history

interviews

The research students went to their places of origin and found the last generation of old people who still have the knowledge of the traditional way of building and planning their settlements.
The interview questions covers topics like building regulations, water supply, building materials, climatic design, functions of spaces, etc...

[S] ite Survay

Additionally to the interviews the researchers have conducted surveys of buildings within the area of origin as example case studies to support and deepen the knowledge given through the interviews. The surveyed buildings in 2011 are mostly depleting ruins since hardly any existing and still in use loam buildings could be found

[D] ocument Research

To support the investigation of the case study buildings of the origin places, additional sources of information is gathered through old pictures, paintings, documents, certificates, publications, etc.

EXHIBITION

Traditional Building Knowledge [TBK] exhibition and conference 2011

Traditifurther research and analysis

transfer of knowledge

Manual to Future Building Knowledge [FBK] 2012

German University of Oman
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Transcript of Interview

Traditional Building Knowledge in Oman

Ibra ابراء

CONTENT

Department of
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of Technology in Oman

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DESCRIPTION

Description

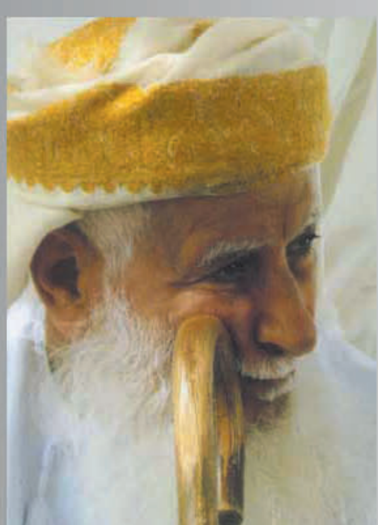
Location: Al-Munzifa is located in Ibra Region which is 22°41'38.62"N 58°32'08.66"E.

Climate Design: Houses are oriented towards wind direction, slits and Openings on walls are made for light and air ventilation.

Urban Setting: Al-Munzifa was surrounded by a city wall with 35 gates. the gates lead to farms located around the city wall. the servants houses were located next to the gates. moreover there was a hierarchical pathways that connected the houses and public areas. In addition to wind direction, the houses were also built according to the stream of Al-falaj, to make water more accessible. Ibra is surrounded by a number of watch towers for security and used as a defense system

Topography: Al Munzifa was originally known as an oasis located between mountains where many different falaj streams passed through it and that is how the name was derived .

Portrait



Quote :
„Arabs preferred to live close to each other"
- Said Salim Said Al-Gathi

About

Name: Said Salim Said Al-Gathi

Profession: Sheikh of Al-Mutaradh

Age: Eighty eight years old

Date of Interview: 19th December, 2011

Location: Said Salim's Residence

About: At the age of 17, travelled to Eastern Africa for business trades and lived there for almost 15 years. Later lived in Ibra and was assigned to be responsible and look after the town and community. Moreover still have the connections with the government, when dealing with community problems and solving conflicts.
Education: learned and educated in Ibra, Knowledge was based on Al-Shariaa Al-Quran and grammar and rhetoric.

Interviewer: Rula Al-Harthy

Transcript

Interviewer: Rula Al-Harthy / Interviewee: Said Salim Al-Ghathi

Rula: To start with, I Already know that Al-Munzifa is situated In Ibra that's 3km away from Al-Mu'taradh.
Rula : In General, Could you estimate Al-Munzifa's built-up area?
Said: Arabs enjoyed living close to each other, some paths were narrow and some were wide enough , there weren't cars in the past , Al Munzifa was also known for Mirkadh.
Rula: Al- Mirkadh, that's the race track , right?
Said: Yes. It was from Dirwaz Al Alawiaa thats the eastern gate of Al Munzifa to Dirwaz Al Haidara the west of Ibra.
Rula: Ok. what's about spaces or inner roads in between neighbors doors?
Said: Its different, depends on the houses and how it is oriented.
Rula: Are there any restrictions?
Said: They weren't any restrictions. the town was controlled by Al- Darwiz from east to the west to the west and night they're close for protection.

Rula: What about the public area? As for the public area, How were they used? if market as an example, how were these places maintained?
Said: People first meet in mousqs that's five times a day , then they meet in the majlis (Sabla) , no TV , people communicate and share knowledge.
Rula: Next people met at suqs?
Said: If its needed !!
Rula: Were they any restrictions on dress codes?
Said: No not as i remember, people meet every day after noon's prayer until Al - Maghrib.
Rula: Was there a certain person, responsible for looking after the Majlses, Mousqs?
Said: No one, the community worked as a team and were very cooperative.
Rula: As for the walls, the „facade" , how were the doors / windows situated for privacy?
Said: Some of the houses their doors were built from aside made from strong thick wood imported from Zanzibar.
Rula: What about the water restrictions, the Falaj rights? ownership and duties? how was water distributed equally among community?
Said: Al -Falaj's were also owned by some people called (Haq). Some had more some less, its distribution is based on time, depending on sun during morning and stars during nights.

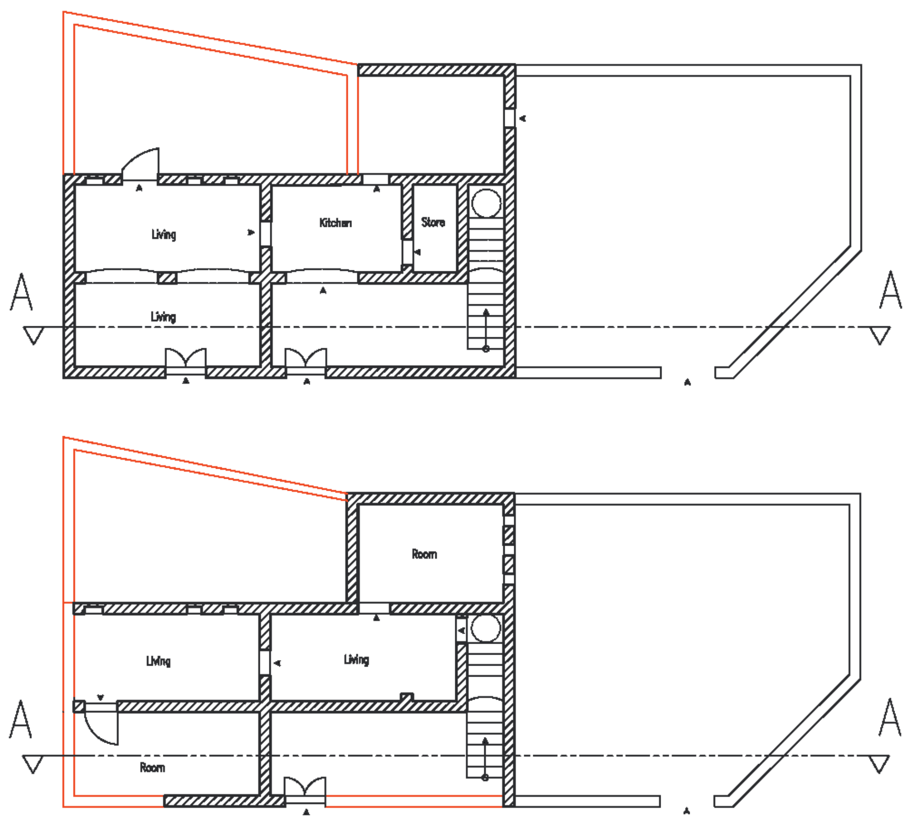
Transcript

Rula: What if someone had more time than is needed , how is it solved , is there any one responsible ?
Said: People understand each other at that time , so no one was needed to be watched?
Rula: As for construction using materials; most houses were built out of mud , loam and wood was brogan from Africa, were there any restriction at system used in construction?
Said: Construction was based in a typical Omani style , using stones as foundation and bricks as load barring walls. As for the roof , its supported by wood trunks and palm trees frond tied together using palm fibers, and they create floor stabs. And most roof in Oman were formed by this system.
Rula: Where there certain places, site, were material such as brick were prepared? and how were such materials transported?
Said: Animals, donkey mainly used to move luggage's or goods during that time.
Rula: Design elements such as arches, monuments. How was it brought on elaborated? Were the designs different from other buildings?
Said: Omanis were who brought these designs.
Rula: Courtyards, how was it imported?
Said: Having a courtyard in the heart of house is an element where it meant to protect the house and a common space for residents.

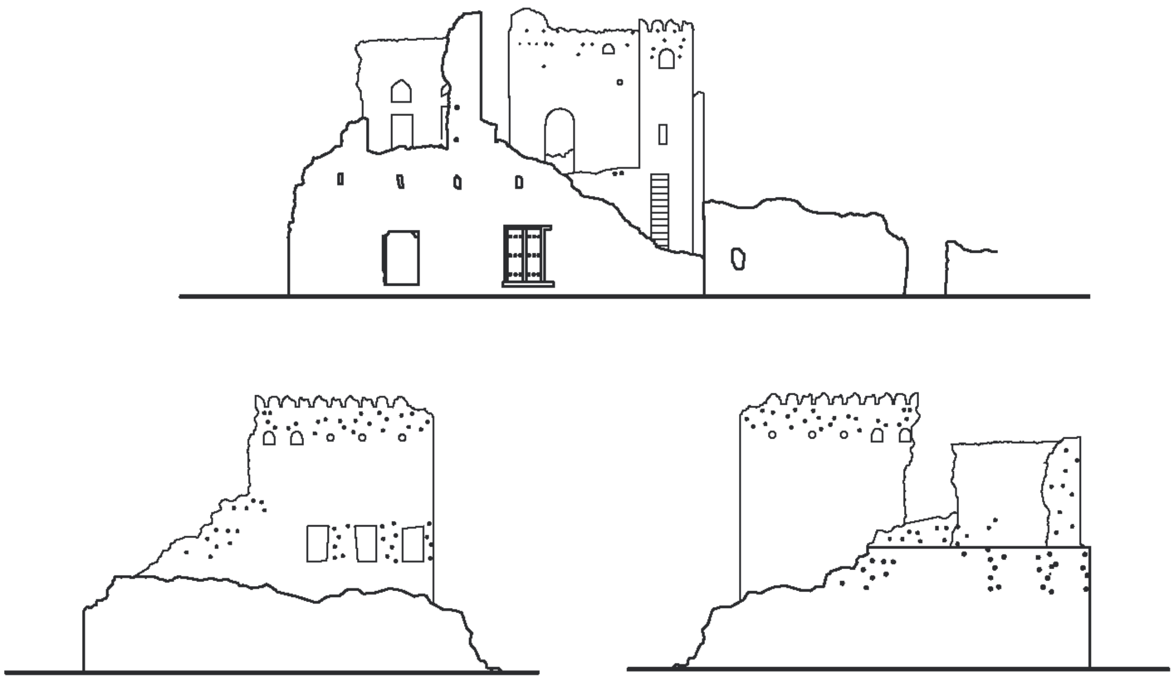
Rula: How was the roof important?
Said: Shade, prevents water, sun heat.
Rula: Wasn't it also used as a watch during wars?
Said: Of course also watch towers on top of the mountains surrounding Ibra, if enemies attack, soldiers on watch towers, give signals using mirrors or guns as a signal to warn each other.
Rula: Basement, were there houses with basements?
Said: Yes! Sure.
Rula: What were they used for?
Said: Mostly used for water supply, store weapons, and things that aren't used daily.
Rula: Coming to the toilet?
Said: Toilets were different . there used to be toilets known as open toilets which were covered with walls and wood and were used for the public. The toilets in the houses were closed.
Rula: The water used for the toilet? where did it go after usage?
Said: The water used in toilets came from Aflaj and Abar (wells).
Rula: Preparation of food , was the kitchen located inside the house or in the courtyards?
Said: No , no ,Omanis used to prepare their food outside in the courtyards

Transcript

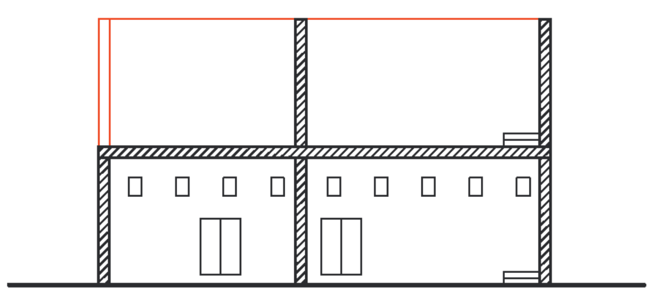
Rula: where did people use to eat their meals? inside or outside?
Said: It depended on the weather, if the weather was cold , they ate outside and when it was warm, they ate inside.
Rula: With regards to the climate, do you think people oriented their houses according to wind or sun direction etc...?
Said: The orientation of the houses depended on the wind direction ofcourse. Most people need wind because the sun is always there, but they needed wind because they did not have air condition.
Rula: Electricity ?
Said : No electricity.
Rula: And Shade?
Said: What shade?
Rula : Shade? for example did they plant more trees for shade?
Said: Trees were planted for many reasons, firstly, to use the branches , fronds, barks, fibers as building material and also for fruits and vegetables , in addition to the shade it provides. for example: palm trees are full of purpose .
Rula: How was the sleeping arrangement? did you have beds? did you share rooms? did you have specific places for men?
Said : Some people had beds while others slept on mattresses .
Rula: How did they cook? fire place? did they have ovens like now a days?
Said: No, no ovens! they used palm tree wood and „simmr“ to make fire.
Rula: Ok Sheikh Said, thank you very much for your time, we gained a lot of information .
Said : Inshallah you did.



Al Munzifa
Location: Ibra
Ground Floor and First Floor Plan
Scale 1 : 100



Al Munzifa
Location: Ibra
Elevations
Scale 1 : 100



Al Munzifa
Location: Ibra
Section AA
Scale 1 : 100

SITE Analysis

Al-Munzifa is located in Ibra which is 3km away from Al-Mu'taradh.

It is surrounded by many natural elements such as the mountains, the Aflaj and the Wadi's.

The built up area is between 200 – 250 sqm for residential buildings and up to 400 sqm for the sheikh's house and public areas.

Buildings were mostly two to three floors high and mostly had basements.

Most residents were either farmers or sheep herders and the Sheikh was responsible for solving conflicts.

STREETS Analysis

There were different types of streets: wider streets connecting the main areas such as the different gates, public areas such as the hospital, the mosque and the souq. These roads barely fit a car as there were no cars back in the day, although they were very suitable for horses and donkeys etc...

The streets were also used as race tracks for horse races "Mirkadh". The races were conducted between the Dirwaz Al Alawiaa which is the eastern gate of Al Munzifa to Dirwaz Al Haidara which is the west gate of Ibra.

Public Areas Analysis

The main public area used, was the mosque as people met there five times a day. They also met in gathering areas known as 'Sablas' or 'Majlis'. People also met in the public souq and visited each other often.

IBRA

WALLS Analysis

Al-Munzifa was surrounded by a city wall that containing 35 gates. Farms were located outside the gates.

IBRA

WATER Analysis

People mostly used the Aflaj as a water source where water was distributed based on time, using the sun during the day and the stars during the night.
As Al-Munzifa was known for the abundance of water, most houses had streams running in front of them, in addition to have one or two wells inside their courtyards.

IBRA

MATERIALS Analysis

Stone from local mountains and Wadis

Hay (fiber) from palm trees used to tie building materials together
Local Sidr tree wood used for floor slabs
Local Palm tree wood and fronds was used for floor slabs and roof construction, some wood material were imported from Zanzibar or India.
A mixture of mud and gravel found from local sites.

IBRA

STRUCTURES Analysis

Construction material consisted mainly of stone for the foundation of buildings, a mixture of loam for the walls and a combination of palm tree trunks, mud, hay and gravel for floor slabs. Roofs were made of wooden trunks for support and palm tree fronds which were tied by palm tree fiber.

Arches were made of layered stones with different shapes this shows the influence of design caused by trade and knowledge collected from different cultures.

IBRA

PLANNING ELEMENTS Analysis

Many houses had a basement which was used mainly for storage of weapons and water. Houses have two to three floors. The first floor was mainly used for gathering and eating spaces. The second floor was used for sleeping arrangement. The roof was mainly used to watch out for intruders.

Many houses were courtyard houses. Courtyards were important and were used for security reasons and also for the privacy of the residence where the residents of the house can use the courtyard as a private communal space.

Kitchens were located mostly outside the houses in the courtyards.

IBRA

Furnishing and Equipments Analysis

Most houses used mattress for the sitting area and also for sleeping, although some houses did have beds.

For cooking, palm tree wood and “sirm” was used for fire as they did not have ovens. Houses had wells for the storage of water.

IBRA

DESIGN STRATEGIES Analysis

Many houses had a basement which was used mainly for storage of weapons and water. Houses have two to three floors. The first floor was mainly used for gathering and eating spaces. The second floor was used for sleeping arrangement. The roof was mainly used to watch out for intruders.

Many houses were courtyard houses. Courtyards were important and were used for security reasons and also for the privacy of the residence where the residents of the house can use the courtyard as a private communal space.

Kitchens were located mostly outside the houses in the courtyards.

IBRA

DECORATION Analysis

Large shelves were found in many rooms and were used to display weapons, perfumes etc...
In addition to many engraved doors and frames which were used as a decoration element.

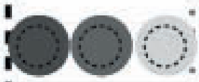
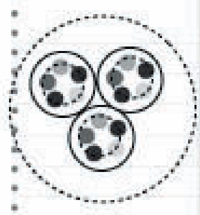
IBRA

CLIMATE DESIGN Analysis

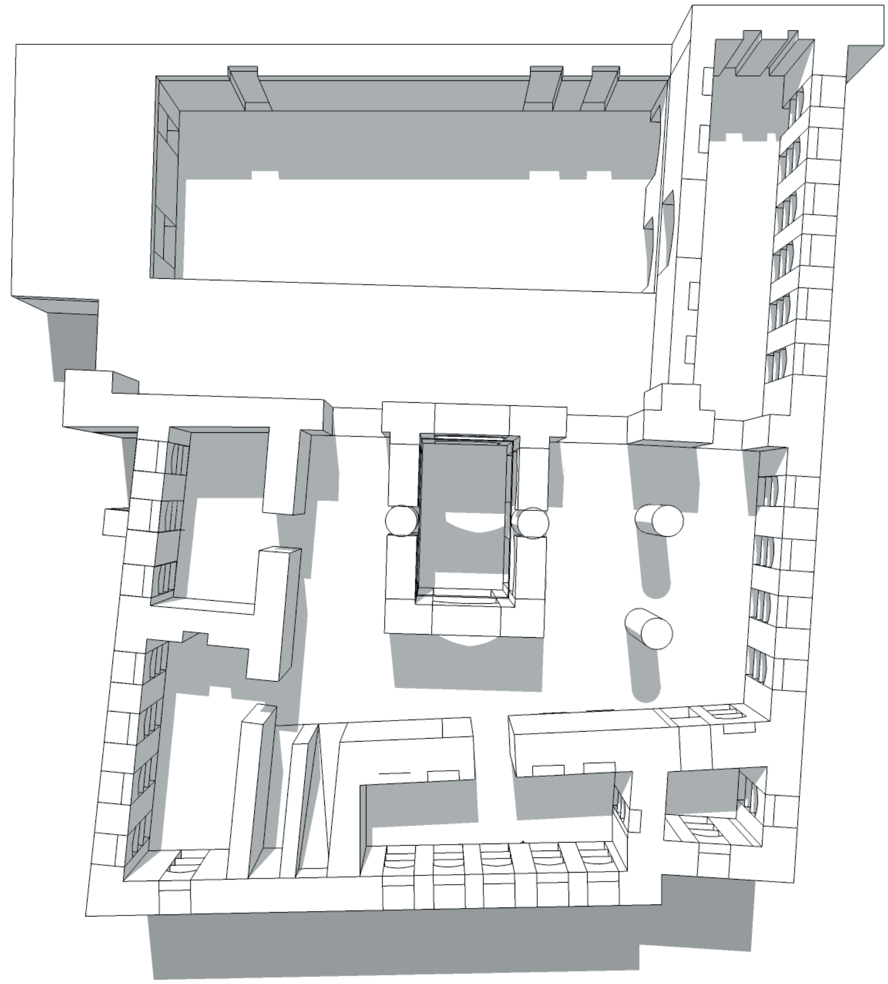
In addition to the consideration of building materials to keep the inside of the buildings as cool as possible, buildings were mostly oriented towards wind direction to allow better ventilation.

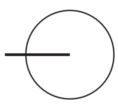
Trees were also used for the shading areas and protecting the city wall.

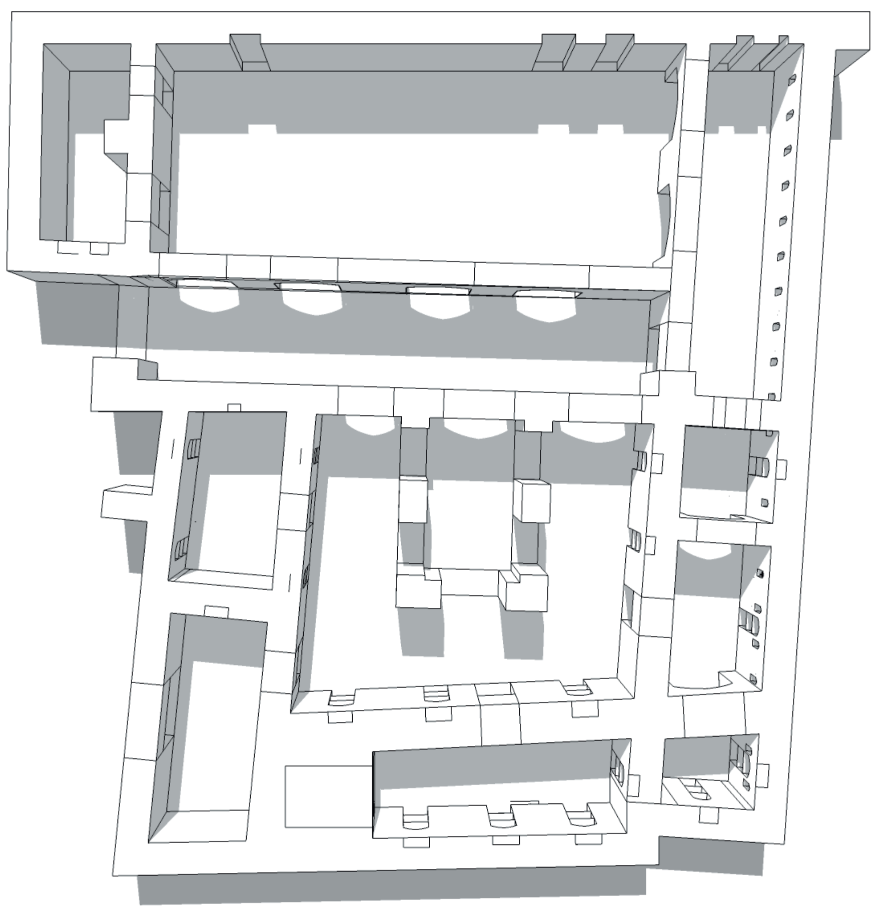
IBRA

AREAS OF ANALYSIS	MNA Mansafah relict of urban cluster	> 1970 <	MCA Muscat Capital Area peri-urban sprawl	> 2011 <	SYNTHESIZER	APPLICABLE CATEGORIES OF CONSEQUENCES	S	E	M
design	vernacular design based on regional and local environment	**The Cut_** new freedoms shall replace old restriction. The sudden loss of inherited traditional knowledge over 5000 years is being sacrificed for a new comfortable western-oriented arrangement of living patterns. >>> further anthropological studies have to be undertaken to document this knowledge before the pre 70ies generation dies away.	imported eclectic design	**Outlook_** principles and strategies need to be developed to feed the solution of the following statements	environmental responsive design	Ecology Morphology		E	M
technology	low technology		high energy technology		low energy technology	Ecology		E	
materials	local materials		import materials		regional located material	Ecology			
built environment	built environment inside > out		decorative facade detached from inside function		environmental responsive design outside=inside	Ecology Morphology		E	M
land use	landuse and zoning by tribal/ common law		government dictated law		decentralised landuse and zoning distribution > additional layer more horizontal to create threshold between government and region	Sociology Ecology Morphology	S	E	M
zoning	clusters, city wall inside and outside interconnected		function zones not interconnected		mixed zones	Sociology Ecology Morphology	S	E	M
ommon space	mutual responsibilities of common space		privatized space		integration into common space through education and learning from history	Sociology Morphology	S		M
community	tribal community centered in decentralized areas; awareness of the society		scattered function sprawl; separated		neighbor hood decentralized	Sociology Morphology	S		M
									
market	local markets		national centralised market		regional local products decentralised markets; free trade systems	Sociology Morphology	S		M

First floor (reconstruction)







Ground floor (reconstruction)

MFA Al Mansafah

West elevation (2011)

South elevation (2011)

Al Mansafah South (2011)

Al Mansafah North (2011)

MFA Al Mansafah

Interior courtyard (2011)

Interior wall elevation (2011)

Appendix III ‘My home is my castle’

Addendum → 0520 Present urban settlement case study, Oman

The case study of Al Khoud is part of a university study called ‘My home is my castle’ (building analysis of contemporary residential villas in Oman) conducted in the summer 2011 by the author with students of the 4th semester of the faculty of Urban Planning and Architecture at the German University of Technology in Oman. A building survey of 30 villas resulted in each: Siteplan (Scale 1/500), floorplans, sections and elevations (1/50), facade vertical details (1/20), roof details and material surveys for each structure. Thus the following detailed insight of a contemporary residential building in MCA can finally be compared to the previous case of MFA in the past, in terms of this study’s inherent goal of analyzing the inter-connectivity of system components (→0530).

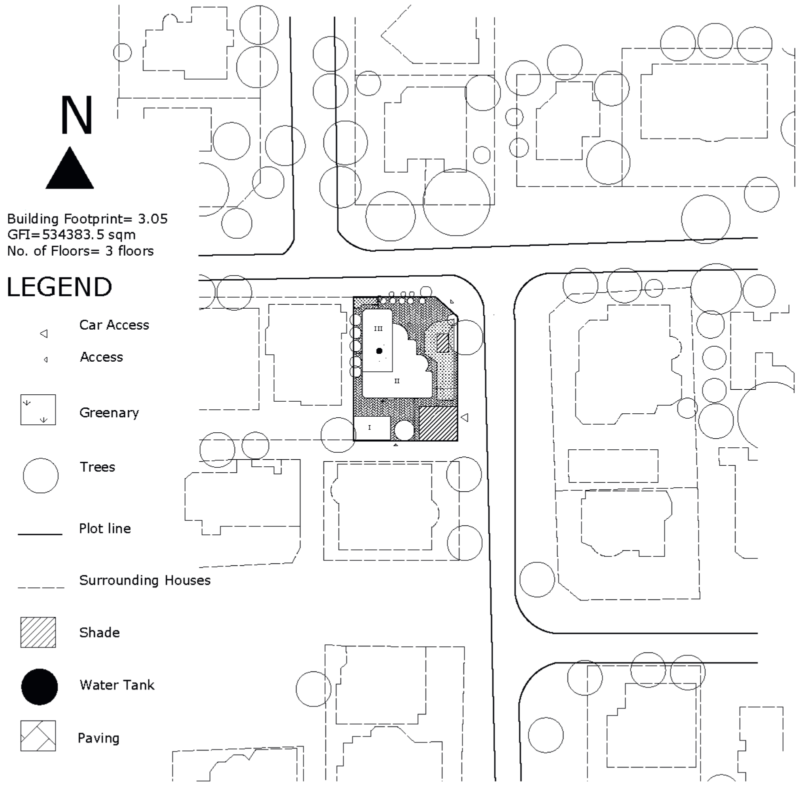
The following appendix shows an except of the 30 villas including the documentation of the case study in →0520 MCA (Muscat Capital Area).

Research participants: Alisraa Al Saadi, Amr Al Zadjali, Asia Al Lamki, Asila Al Busaidi, Ayesha Rahman, Fatma Al Rahbi, Fouz Al Busaidi, Haitham Al Rawahi, Hamida Al Riyami, Hanan Al Riyami, Iman Al Ajmi , Khadija Al Mandhari, Mahir Al Arafati, Maiysa Al Mandhari, Maryam Al Taei, Mohammed Al Madhani, Nadeen Tall, Nasser Al Sayegh, Nibras Al Molahi, Noor Al Raisi, Ricky Vinayachandra, Rola Al Harthy, Sabreen Al Badai, Sabrina Ahmed, Saleh Al Adawy, Shadha Al Mazrouai, Shaima Al Raisi, Sultan Al Zadjali, Talal Al Haremi and Taleed Rose with the support of Dipl.-Ing. Tom Held.

Maiysa Al Mandhari

Situation and Theme

It is a standard architectural style in Oman, commonly seen in Muscat. With typical Arabic design, arched windows, traditional doors and Arabian influenced gypsum around the windows and doors.
The openings of the house are mostly facing outwards to the street, as they let in the most amount of light to the most used spaces and rooms of the house.
The walls of the house are beige in color as permitted by Muscat municipality.
It might seem typical, but in fact it is not the typical rectangular shaped house. Rather curved walls facing outwards which as the main feature of the house.



Site Plan

Maiysa Al Mandhari

Situation and Theme

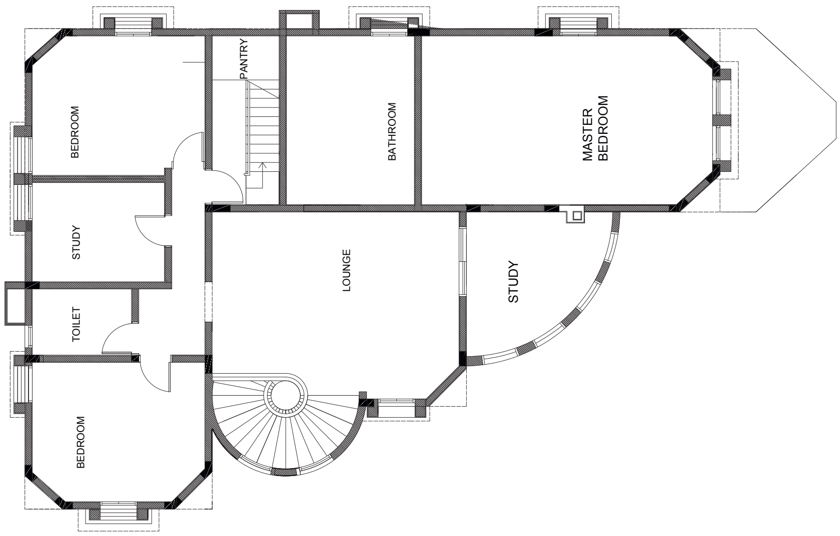
My house is located in Muscat in the area of Bawshar. It is situated on a higher mountainous area in Bawshar heights; it is mostly a residential area but also has a commercial area that includes educational facilities, such as, universities, colleges and schools. There are a variety of other facilities nearby my residential neighborhood including, a petrol station, small shops, a private hospital, a mosque which is located opposite to my house and a residential neighborhood called Dolphin Village. It is a very quiet neighborhood and the sizes of the houses are quite big. Moreover, the new Muscat expressway can be easily accessed from the area.

Maiysa Al Mandhari

Interior Layout

On the first floor: three bedrooms, a study room, living room, a pantry, and a multi-purpose room which was a study.
A corridor connects two bedrooms, multi-purpose room, shared bathroom and the pantry leading to the pent-house and roof-top.
The penthouse is a good size room that has a bedroom, seating area and a bathroom.

The main design feature of the interior is to have as much open space as possible, good circulation of light and ventilation and also a flexible use of rooms that can be separated into separate spaces for various functions.

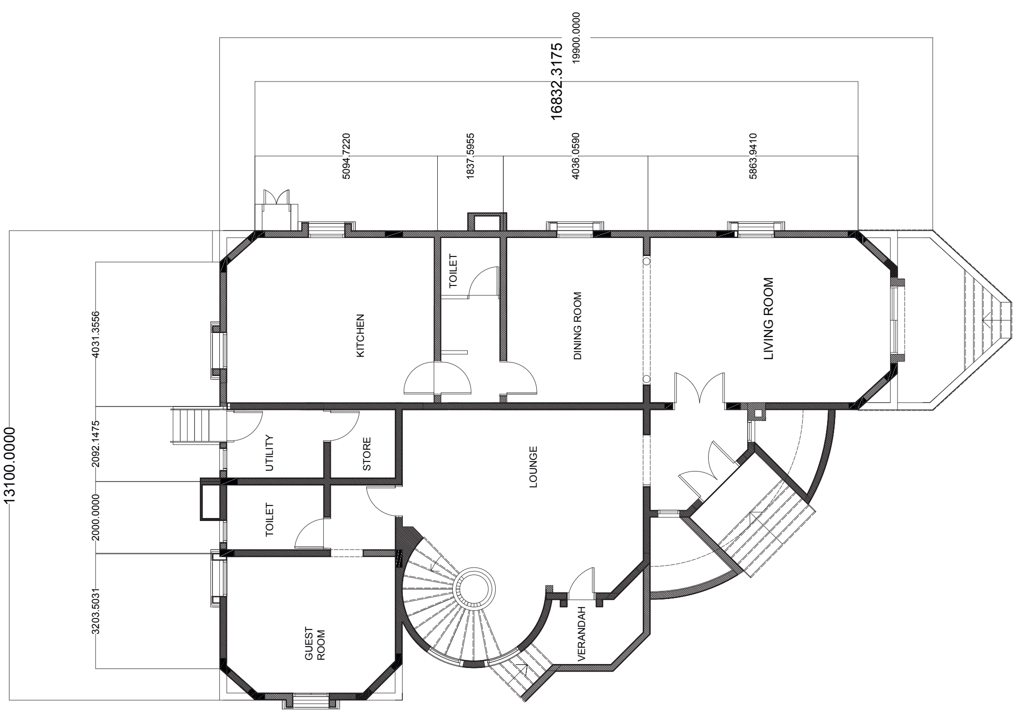


First Floor Plan

Maiysa Al Mandhari

Interior Layout

The interior plan of the house is mostly an open-house plan that is more flexible. Therefore reduce the corridors of the house.
The house consists of two main floors and a half-floor, pent-house floor leading to the rooftop.
The main circulation in the house is a semi spiral staircase that is open to the living room on the ground and the first floor of the house.
The ground floor consists of three main doors leading to the outside situated in levels of privacy.
The functions on the ground floor are: a guestroom, dining room, living room and a kitchen.



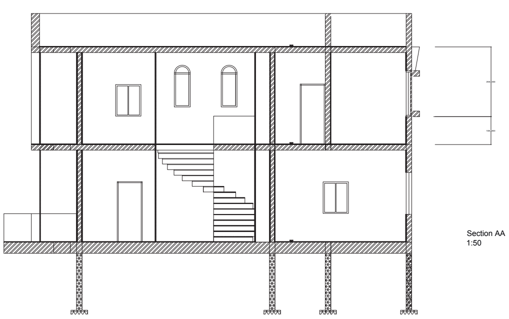
Ground Floor Plan

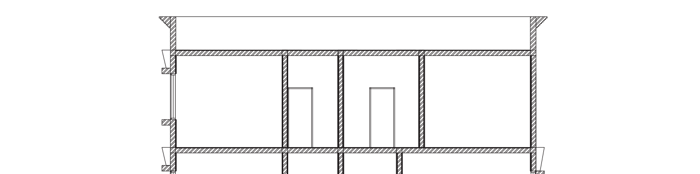
MCA Al Bawshar

Facades

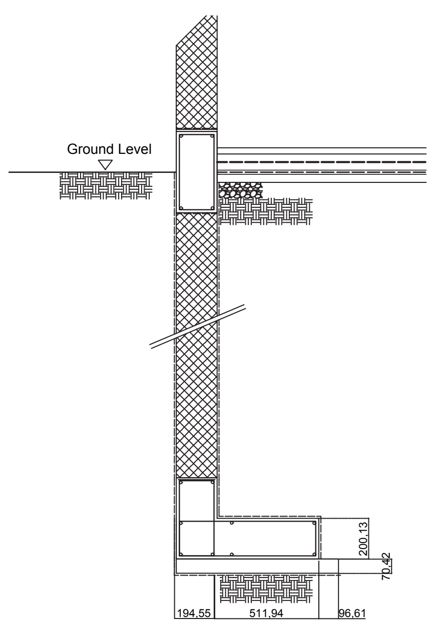
Above the main entrance we can see four big windows that are of the study room.
On the second side of this main elevation we can see the car park, the entrance a window into the guestroom on the ground floor. On the second floor we can see a window looking into a bedroom and three windows looking into the family living room and main circulation space-the stairs.
The remaining two elevations facing the neighboring houses are mainly where the bedrooms, bathrooms, laundry room, plumbing and electricity wires are.

Elevations





Sections



Maiysa Al Mandhari

Construction and Structure

The house is built onto a pad foundation as the soil isn't strong. A pad foundation carries load from a single point which are the columns. This type of footing spread the load where the columns are in the middle of the footing which makes it a loadbearing structure.
The excavations of the footings are 2000 mm deep below existing ground level. The foundation was laid over hard ground or undisturbed strata after excavations. Looking at waterproofing, all the surfaces that are open to soil have been covered by layers of Bitumen.
The columns and the beams are connected to each other. The beams are surrounding the house and are also present where the rooms are separated. And they are basically connected by the columns on both floors.
The house is a filigree construction, where elements connect with each other to make a structure. Looking through a section, the thickness of the walls are mostly 200mm.
All the structural members are meant and designed to handle to dead loads on them and the live loads such as the typical floors and the staircase.

Maiysa Al Mandhari

Exterior materials

EXTERIOR GYPSUM

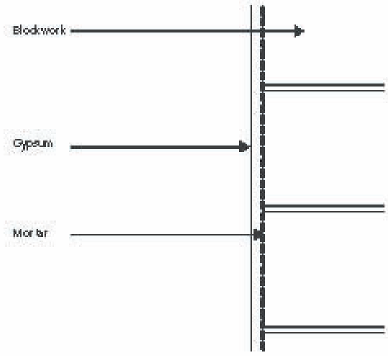
Decorated gypsum tiles are placed on the borders of the doors and windows of the house. They are xed by a
bonding material straight to the brickwork. They frame the openings of the house and have an Arabic touch to
the house as they are geometric patterns. The mateial is light weight, crack and shrink resistant, durable, re-proof, easily installed and eco-friendly.

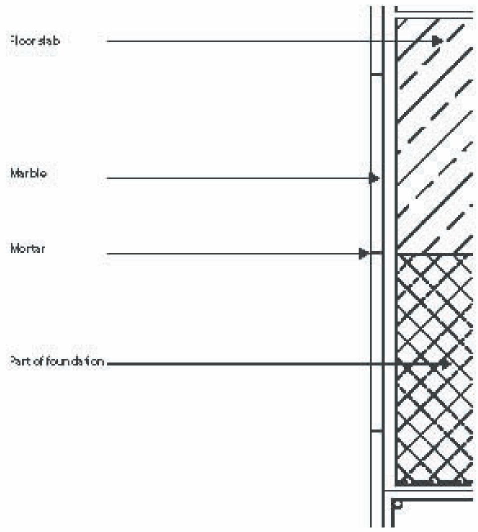
Exterior paint render

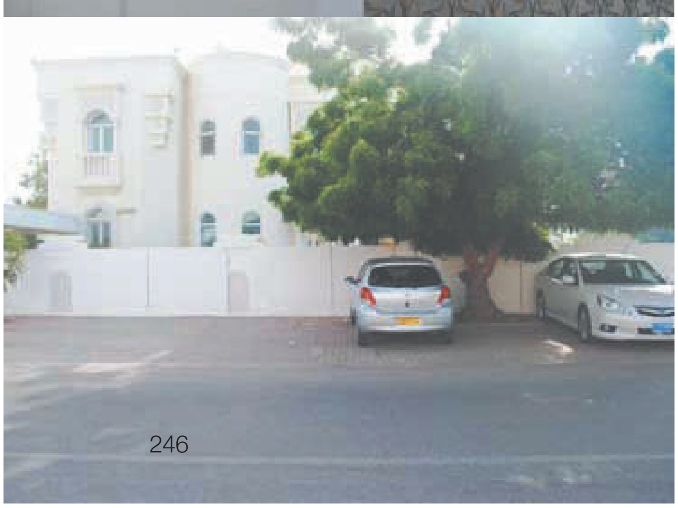
The paint on the exterior wall is an uneven surface on all the exterior surfaces. Its beige in color and is a basic coat for protection. The rendering is used to improve the appearance and acts as weather resistant. It is a thin premixed surface of sand, cement and lime plaster to the brickwork.

EXTERIOR MARBLE ON WALL

On the exterior walls of the house, local marble tiles are placed all around. They are placed up to one meter from
the ground to protect the house from salt as it would cause damage to the exterior walls. The design pattern is
that the marble pieces of 30cm by 15cm are vertically placed side by side and they are of a dark shade of brown.







Maiysa Al Mandhari

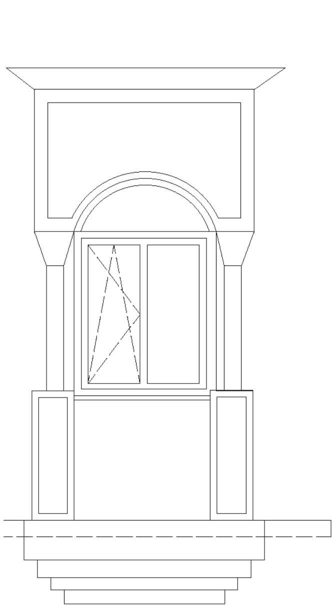
Facades

The house is white to beige in color. The influence of the design is of Arabic background, which is seen mostly around the openings.

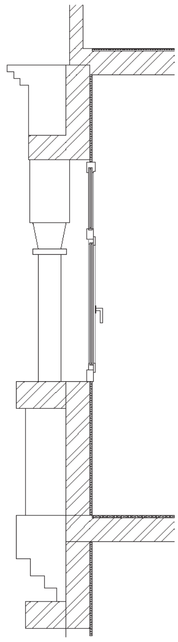
The four elevations to this house are different from each other. We have two main elevations, and those are the ones facing the road as the house is on a corner plot. The two remaining elevations are facing walls of the neighboring houses.

The two main facades of the house are facing the street. They are almost all curved; the non-curved walls are in the corners.

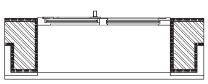
In one elevation you can see the main entrance to the house that is mostly used by guests, which is also connected to the main sitting room. On the upper floors of this elevation you see the master bedroom and the bedroom of the penthouse. All of them have openings. The main sitting room has a big window that open to the garden, the master bedroom has two windows and the penthouse has a large window that opens to the outside.



External Elevation

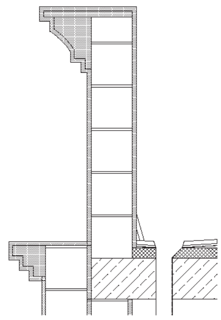


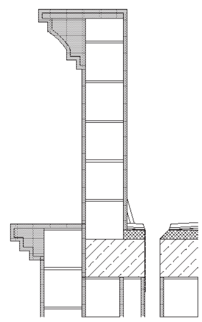
Section



Plan

Facade Section





Maiysa Al Mandhari

Openings

The house has openings on all sides. The most openings are on the sides facing the road and the sides that get most light into the house, as for the doors, two main doors are seen on this side. The other openings are mainly windows of bedrooms and the laundry room, and one door from the kitchen leading to the outer kitchen, car park and garden.

The types of windows on the entire house are double glazed and sound proof to a good extent. All the windows open inwards and can be levered. However, the two main balcony windows can slide and lever.

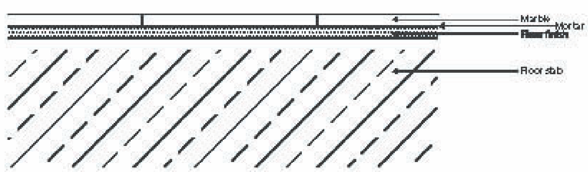
Maiysa Al Mandhari

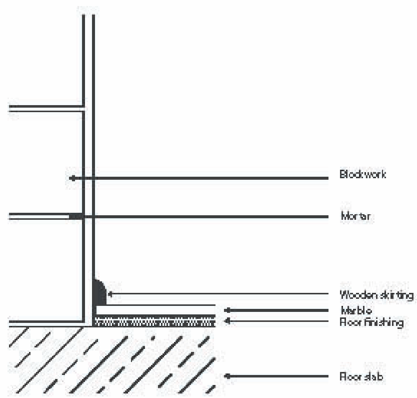
interior materials

INTERIOR MARBLE FLOOR
This Material is a locally produced marble. THey are 30 cm by 30 cm and 2 cm thick, located in all the floors of the public and semi public spaces of the house. THey are fixed using a bonding material above the finishing layer on the floor slab. THe design : it consists of two different shades of brown. The darker shades are placed after a border of the lighter shaded marbles , surrounding its limits.

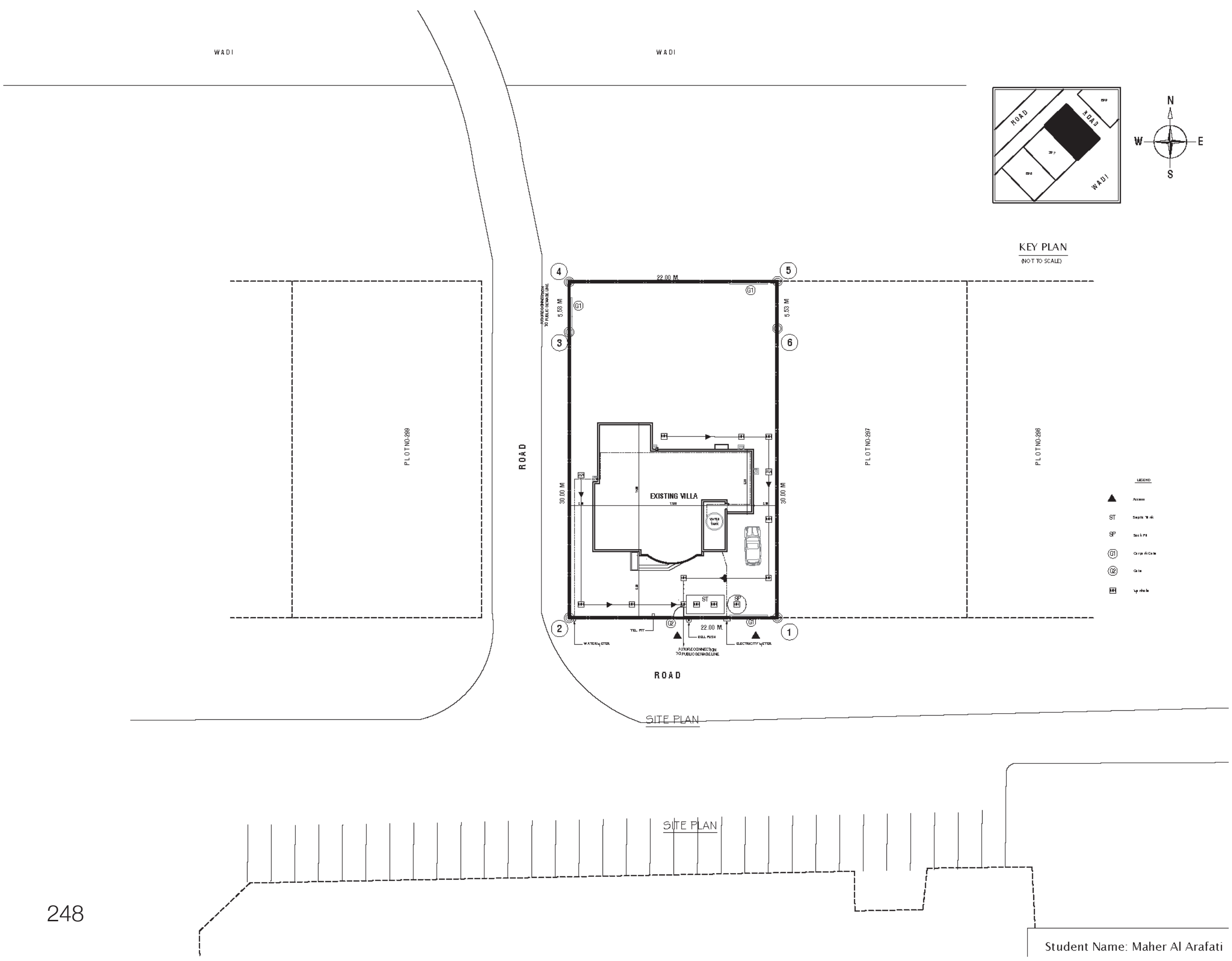
INTERIOR WOODEN SKIRTING
The wooden skirting is placed by the stairs. We have them all around the house as marble and tile skirting.
However by the stairs it is of wooden mahogany material. It is wood here to match with the wooden banisters.
Its pattern follows the stairs.

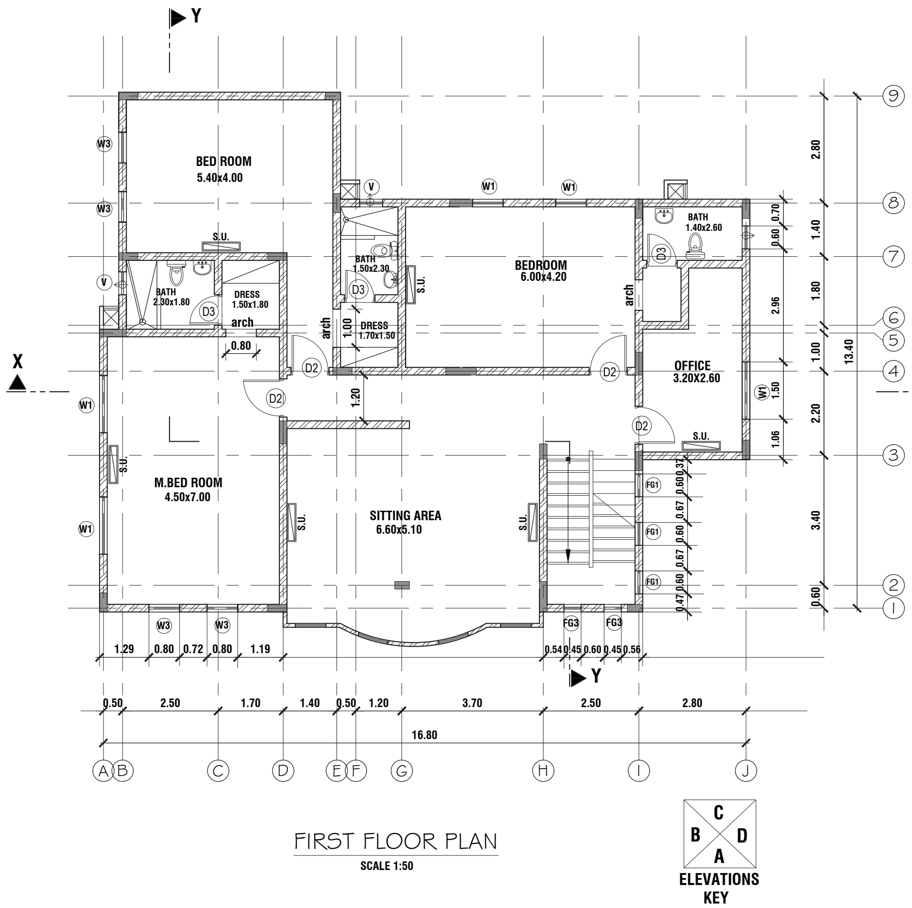
INTERIOR ROOM TILES
The foor tiles are used in all the bedrooms, for their availability and better price comparing to marble. Initially all
the rooms had xed carpets, the tiles replaced the carpets as its easier to keep clean, accumulates less dust and cools the room faster than carpet.





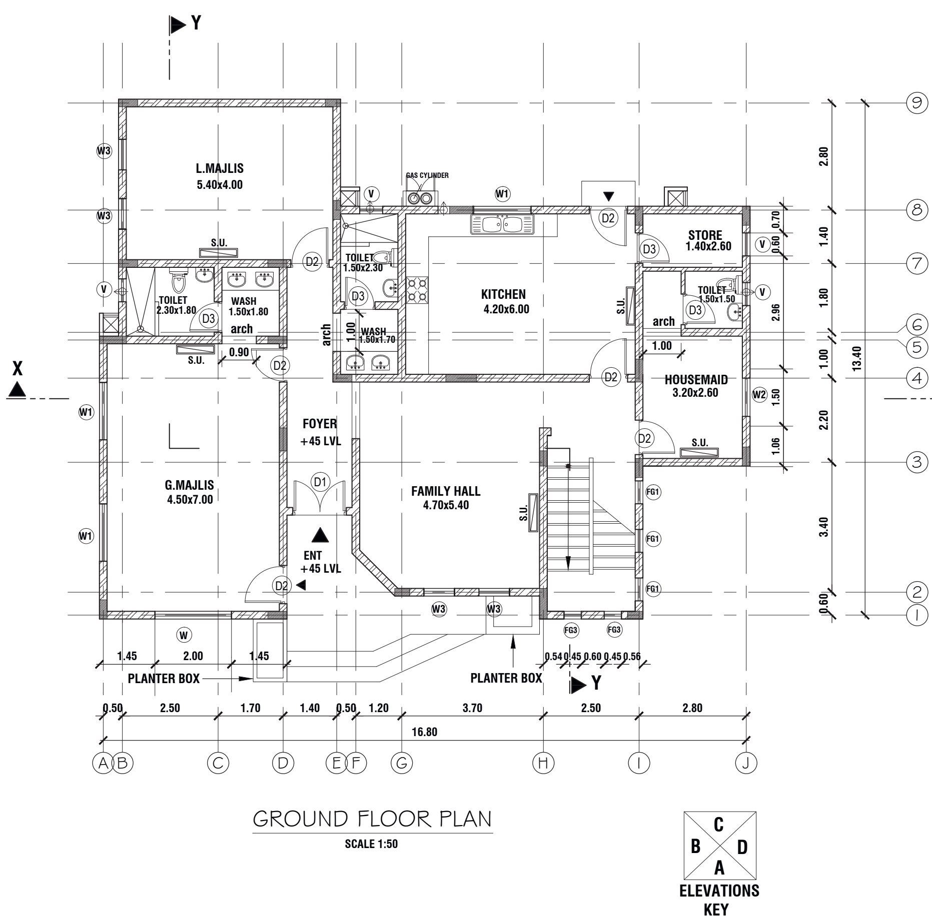
North-west elevation (2013)





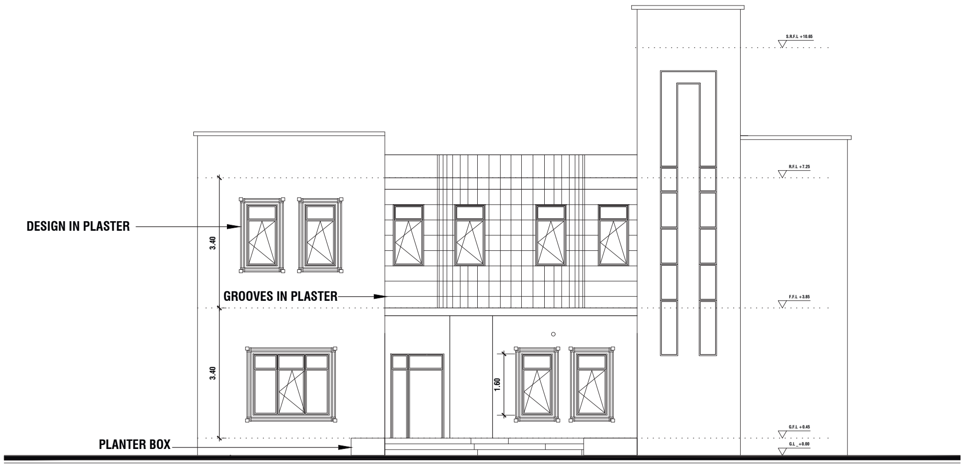
FIRST FLOOR PLAN

SCALE 1:50



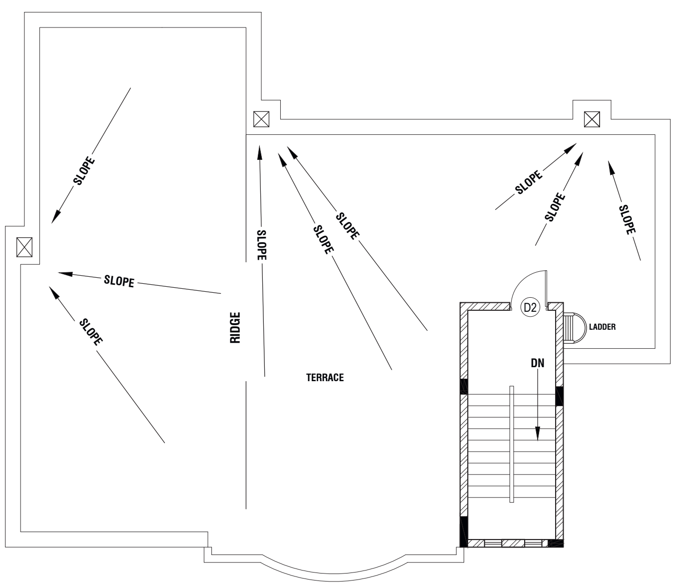
GROUND FLOOR PLAN

SCALE 1:50



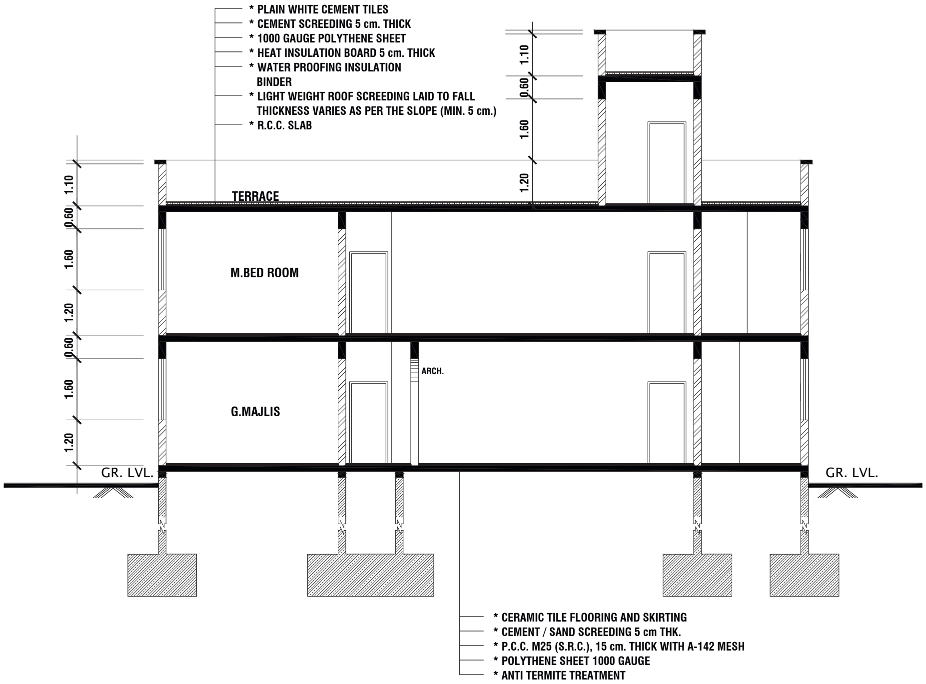
ELEVATION A

SCALE 1:50

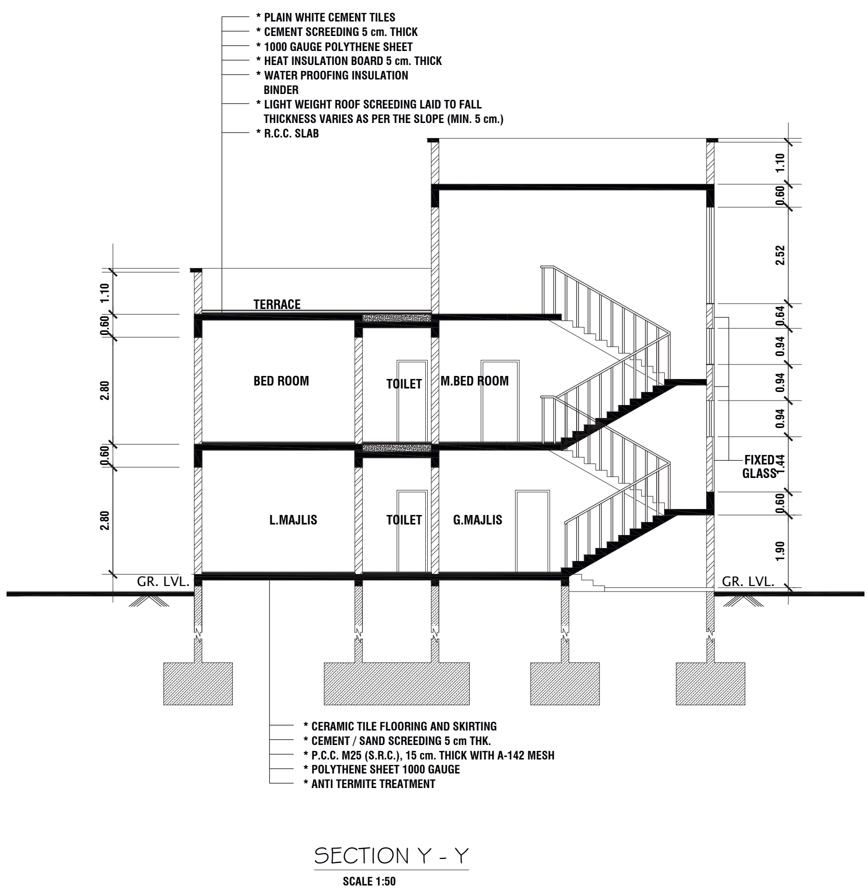


TERRACE FLOOR PLAN

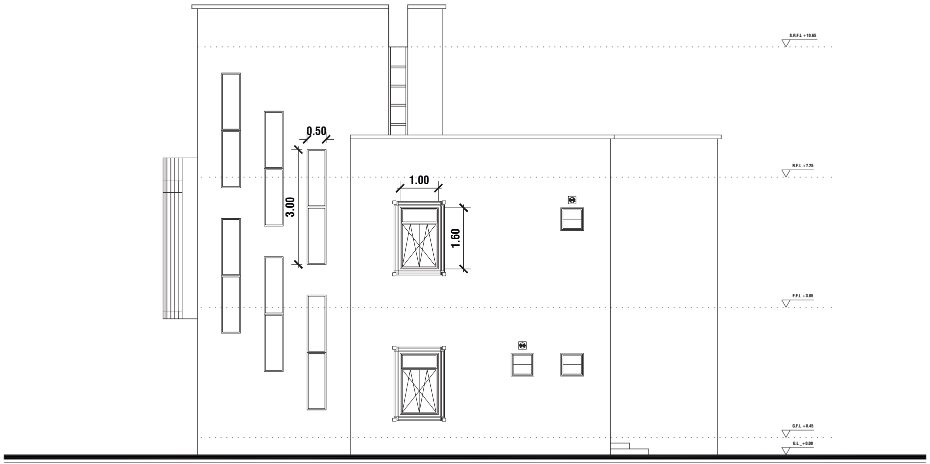
SCALE 1:50



SECTION X - X
SCALE 1:50

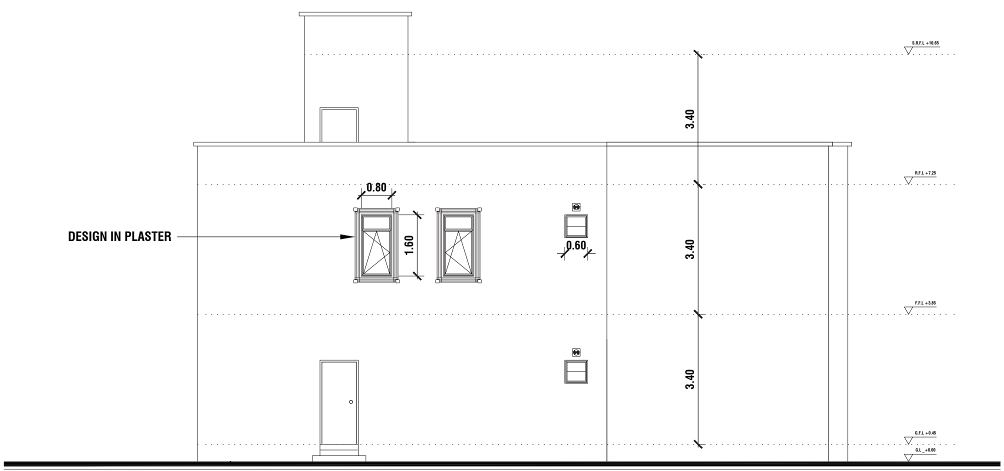


SECTION Y - Y
SCALE 1:50



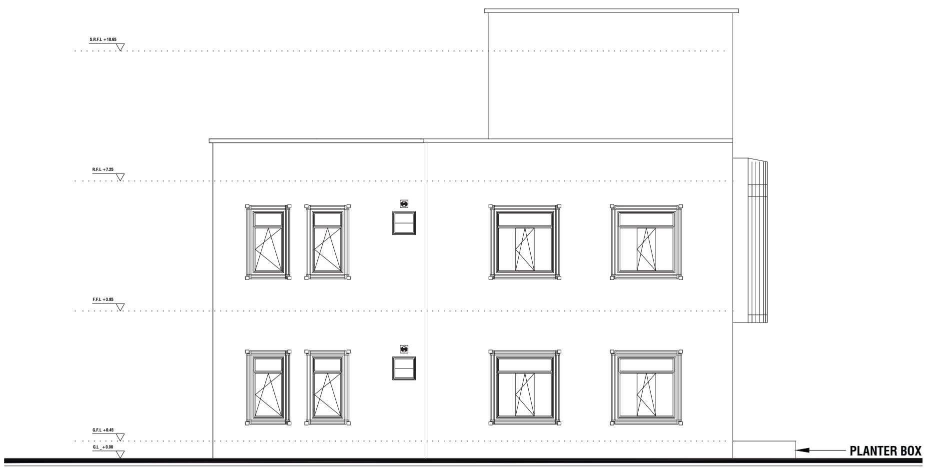
ELEVATION D

SCALE 1:50



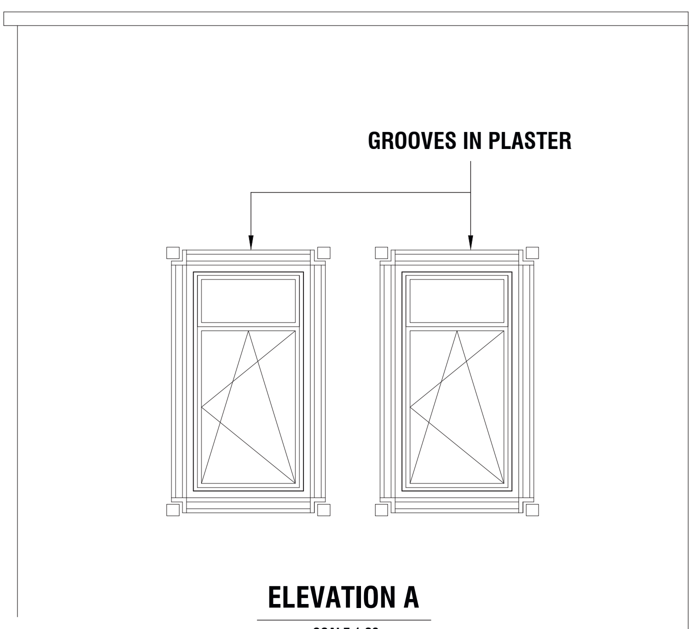
ELEVATION C

SCALE 1:50



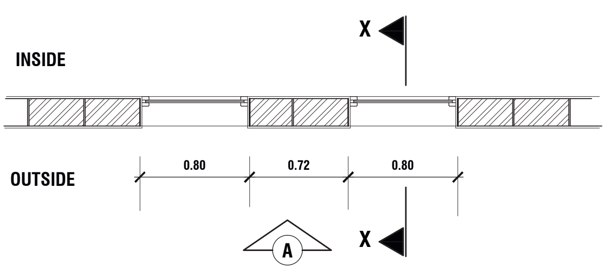
ELEVATION B

SCALE 1:50



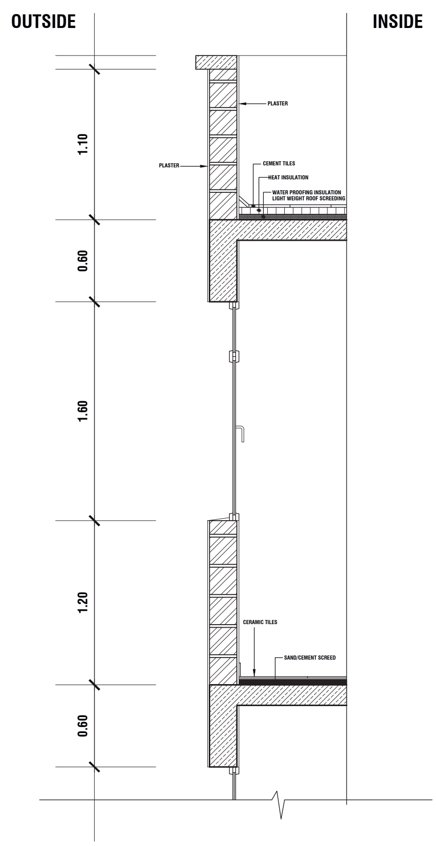
ELEVATION A

SCALE 1:20



PLAN

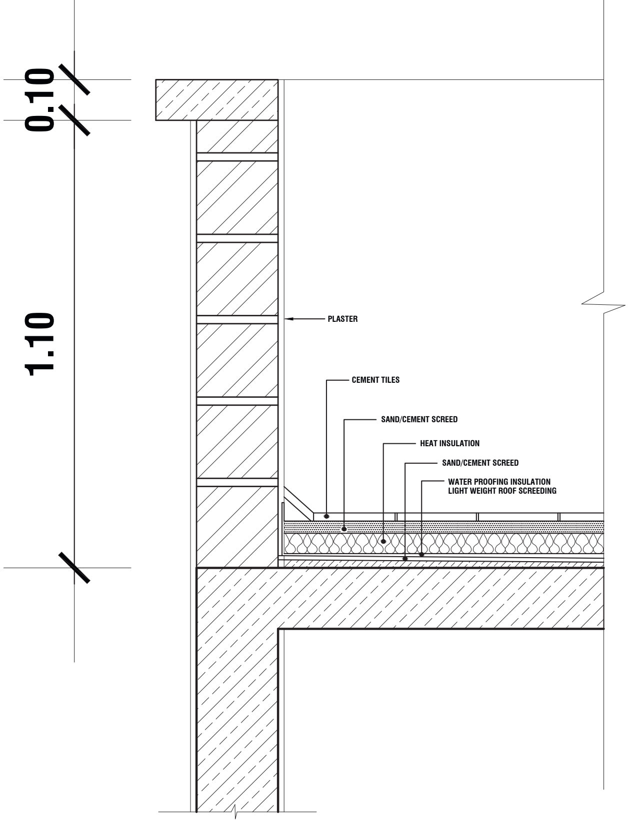
SCALE 1:20



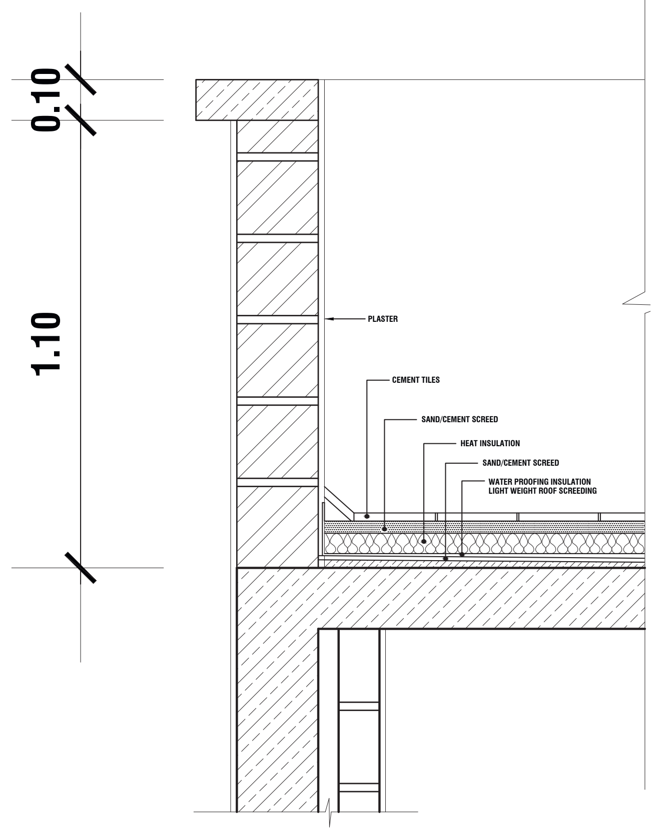
SECTION X-X

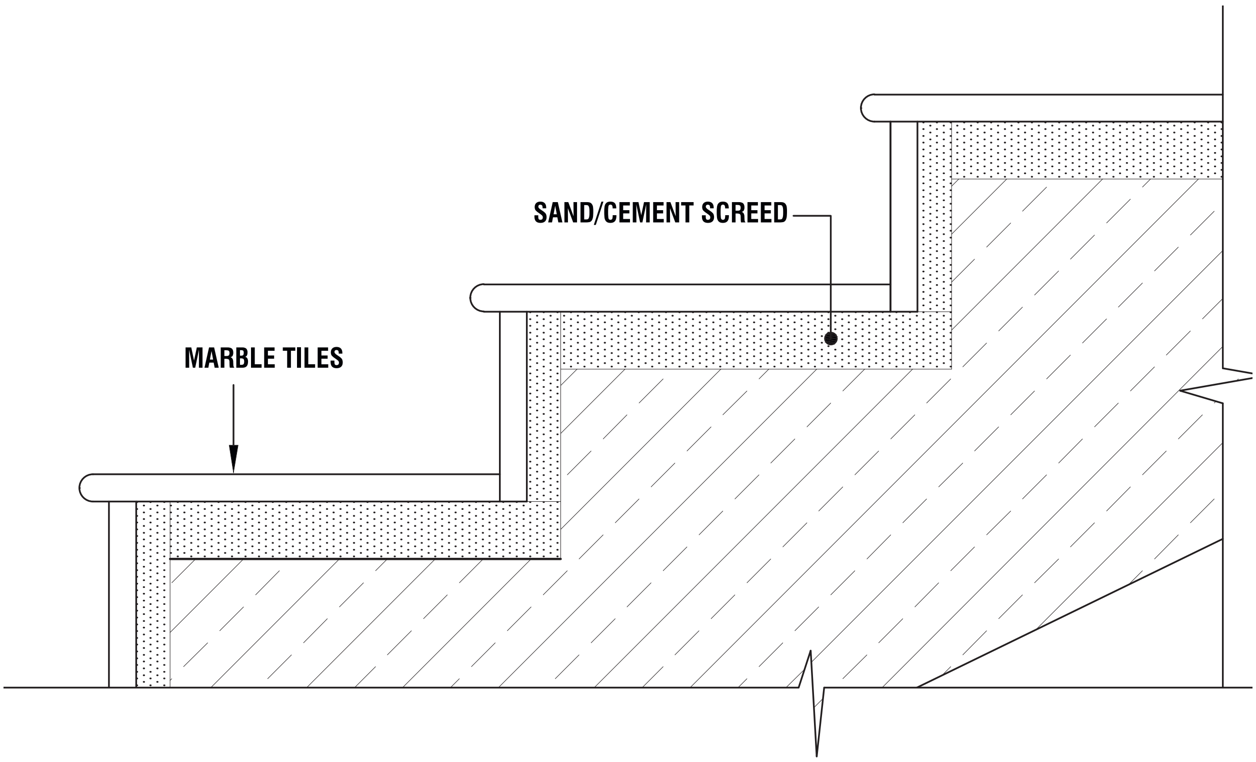
SCALE 1:20

My Own House

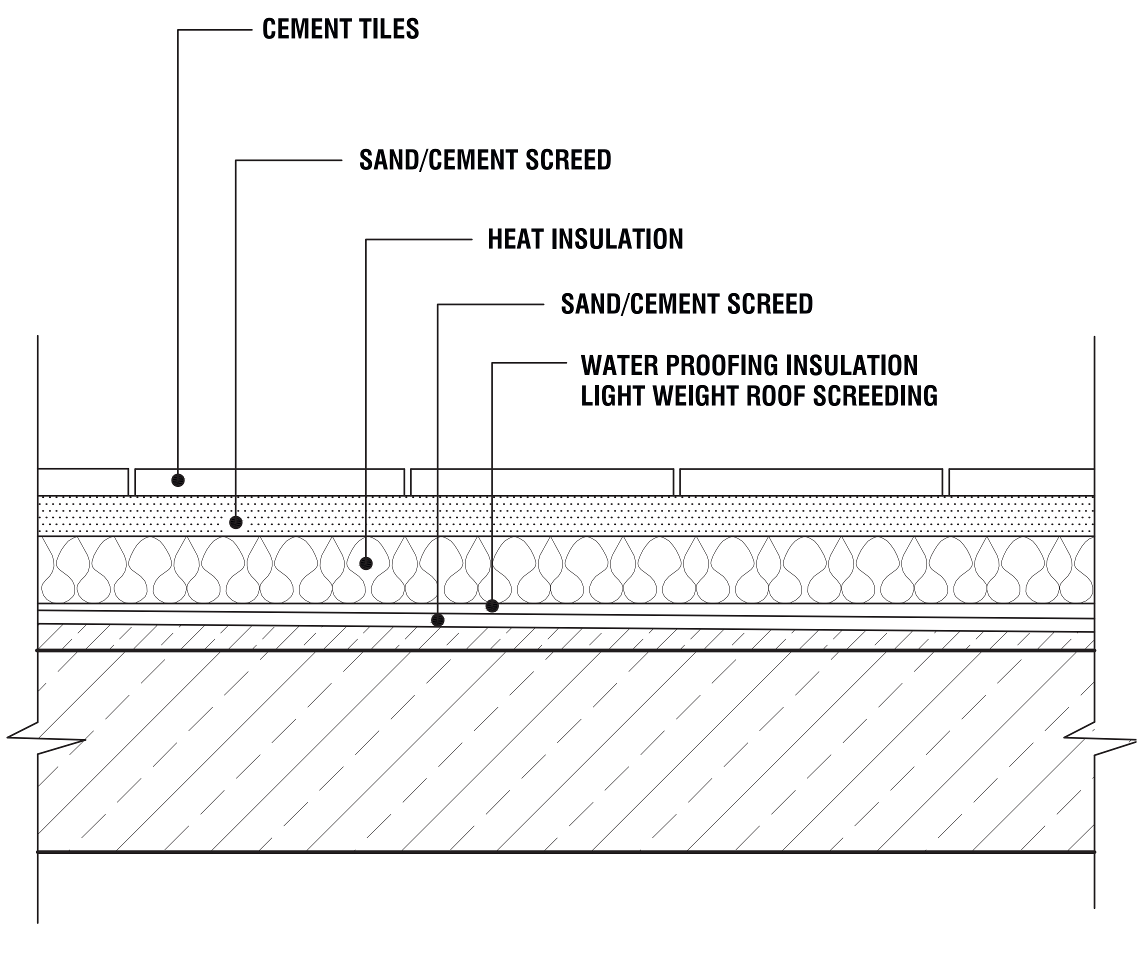


Climatically Optimized Version





MARBLE TILES



CEMENT TILES

Description by Maher Al Arafati:

My house is located in Muscat, the Capital of Sultanate of Oman. It is situated in place called Al Khoud Phase 3. My home is around 15 minutes far away from Muscat Airport. It has been built in November in 2009. The house is built in a plot size of 782 meters square. The plot is in a corner position with a road in the front and a road in a side and both roads are served with street lights. Where the other side of the plot it attached to another plot. In the back side there is a Wadi and it is around 20 meters far from the house's boundary wall. Opposite of my house there is a mosque and some shops attached to it. There is a Jami'a (a big mosque where Friday's pray is praying in it) and it is around a kilometre. My house is about four kilometres far from Sultan Qaboos University. The house stands in the plot in margins of two meters from sides and six meters from front. The house is connected with all necessary services like potable water, electricity and telephone line.

Interior Layout:

A front of my house there is a space for two cars. The main entrance consists of two steps and a wide land which make possible to take off shoes before entering into the house. Form the main entrance of the house a main corridor is facing you. On your left hand there is a majlis for men while the female majlis will be directly in the front of you. On the right hand there is a living room which is locating in the center of the house. The kitchen is located opposite of the living room where there is on opining in the wall which is in between them. That opining is working as a serving window. The kitchen is large and it has been fully modernized, complete with aluminum cupboards, electric hob and oven, microwave, kettle, refrigerator and a store attached to it. In addition, there is a back door from the kitchen which leads to an open land behind the house which supposed to be a garden in the near future. Upstairs there are three bedrooms, large setting room and an office. Two are equipped with double beds and the third has two single beds. All the house is air-conditioned with spelt unit air-conditions system.

Construction and structural aspects:

The type of foundation used to build the house is Pad Foundation. It has been excavated approximately two meters under the ground to sit the footing. The footings are holding the concrete columns. The columns are continued to the first floor and connected with beams and slabs. The steel size that used for footings, columns and beams is thicker than what it used in slabs. The building structure is a load bearing function. The gaps between columns have been filled by cement block works. The outer skin is of plastered masonry and so do the inner skin. The floors have been used to run plastic pipes which use to run electrical wires to connect whole rooms with the distribution board. The pipes run under the floor's tiles. It has been used different floor tiles such as ceramic, granite, marble and porcelain.

Facades:

The facades have been designed to be simple to give simplicity and beautiful at the same time. The front façade it show the main entrance of the house with a cantilever above it. The main door has been little pushed inside under the cantilever to protect it from the sunlight and the weather. The house has been painted with a light color to reflect heat away. The main entrance's steps are tiled with granite because it is a hard material and weather resistance and the entrance decorated with two flower boxes in both sides of steps. The other facades are quite simple. Almost they are flat walls with windows. The windows are framed with cement groove from outside. The parapet is decorated with a simple projection in the top. That projection is painted with different color to make it easy to notes it.

Openings:

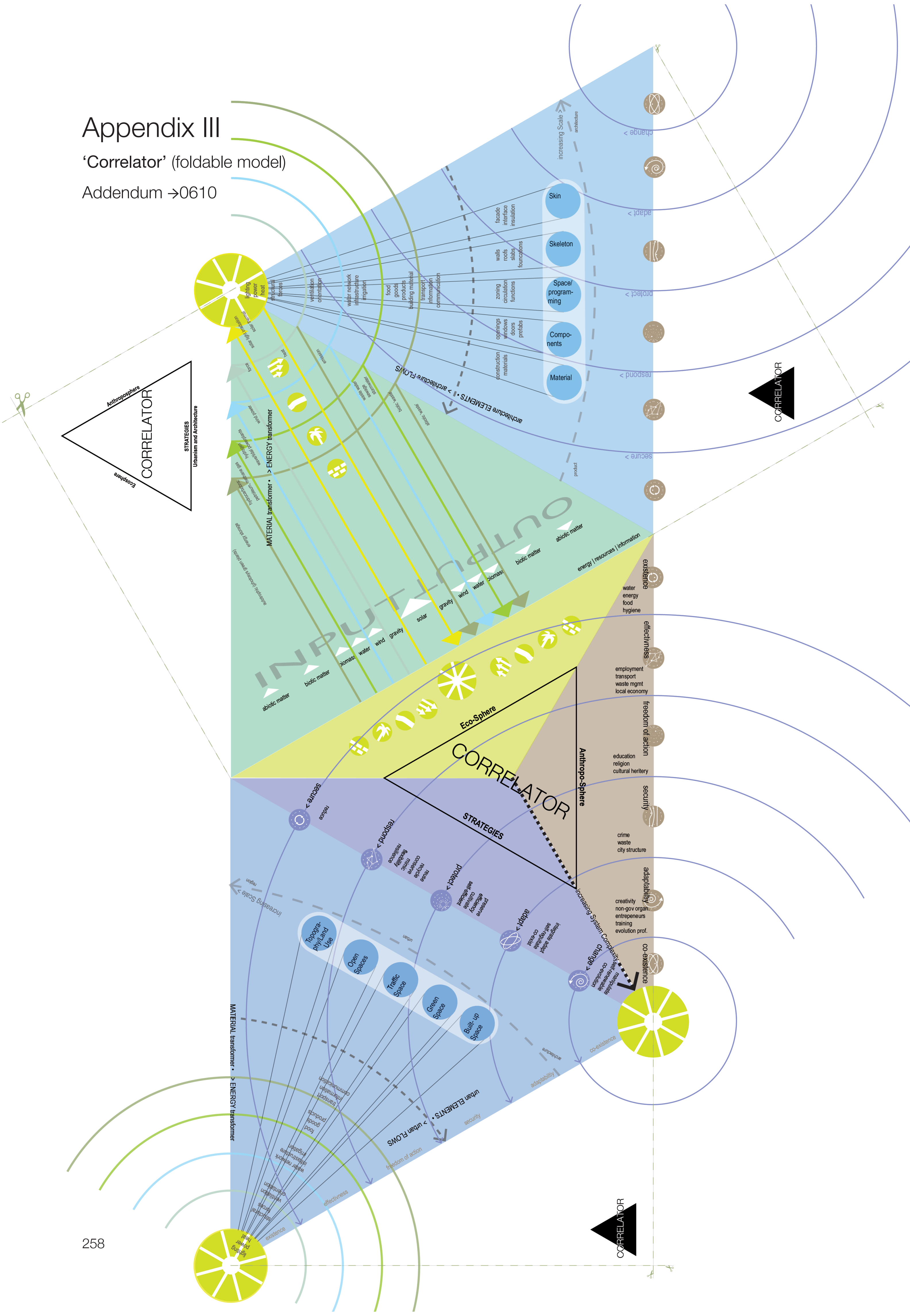
All windows are fixed to be finishing flush with the wall surface from inside except the stair case windows which fixed from outside façade. The top portion of windows is touched the beam itself. That's mean there is no need to have a lintel above the windows while the beam work as a lintel in addition of it is a beam. Windows frames are made from UPVC material with double glazed glasses. It works as a sound proof, water proof and weather proof. Double glazed glasses help to reflect sunlight and reducing heat comes inside the house. There are three types of windows. The first one is a fixed window and that are used for the stair case. The second type is an open able shutter with some fixed parts. The shutter is opening by two ways, from top and hanging the bottom and opening from a side and hanging the other side. This type of windows is used in all rooms. The third type is a slid open window and used in the kitchen.

South-east elevation (2013)

Appendix III

'Correlator' (foldable model)

Addendum →0610



40 years after “The limits to growth” the post oil boom economy affects countries in resource scarce environments like the Arabian Peninsula in the Middle East with expanding urbanisation. Those cities and architectures are based on fossil fuel driven technologies to control the surrounding arid hot climate for the benefits of human comfort. As a result skyscrapers are flourishing out of desert sands. Their ecological footprint in terms of resource consumption and the resulting emissions is nearly six planet earths, but celebrated by imported quantitative evaluation methods from North America or Europe with platinum medals for sustainable building practices. This dichotomy displays the global quest for ‘sustainable’ development on the one hand side and the lack of integrating the inherent bio-climatic, socio-cultural and political-economical prerequisites of those newly developing countries on the other. Whereas traditional desert oases settlements have been as self-sufficient and self-organising systems perfectly interconnected with all prevalent natural resources and cultural conditions inherent to the region. Such integral understanding draws on the logic of the immanent relations of the natural, human and built environment or in other words on ecology.

An ecological understanding is used in this work to determine the qualitative relationships of urban and architectural (built) environments in conjunction to prevalent natural (ecosphere) and human (anthroposhere) conditions. On the assumption that the built environment acts as levelling layer between the human and the natural environment in order to compensate bio-climate conditions for the comfort of social-cultural context desires, the main research question raises as such: How can cities and architectures become support systems (rather than energy and resource consumers) that have the properties to co-evolve as cooperative sub-systems with the surrounding natural and human preconditions under the rules of ecology in general? And in particular: How can the concept of a traditional self-sustaining desert oasis provide future strategies for sustainable development of cities and architecture?

The resulting model provides a correlation matrix that orders elements and flows from the natural to the built environment via considering principles of human systems and strategies of ecological systems. It proposes a template of possible elements and strategies for interconnection, which determine the quality of adaptable, viable and thus ‘sustainable’ urban environments. The Correlator shows possibilities and fields of action for the holistic thinking of architecture and urbanism as support system and thus for the decision-making processes in planning, policy, and the design of the built environment. Finally this work demonstrates strategies for ‘sustainable development’ where the correlation matrix and the knowledge of the quality of ecological network connections proposes an aide-memoir to de-specify the tunnel-visioned expertise of past innovations and prioritises ‘Vernetztes Denken’ for newly meaningful concepts for a new planning culture that enable viable urban and architectural development, not only within desert regions.

Daniela A. Ottmann 2015